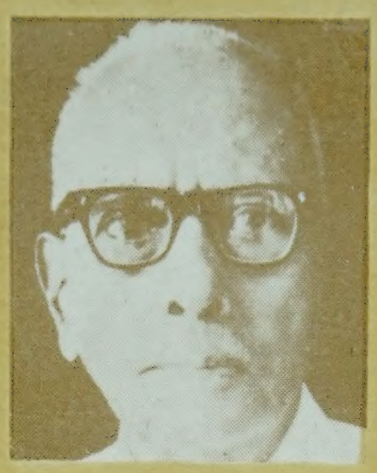
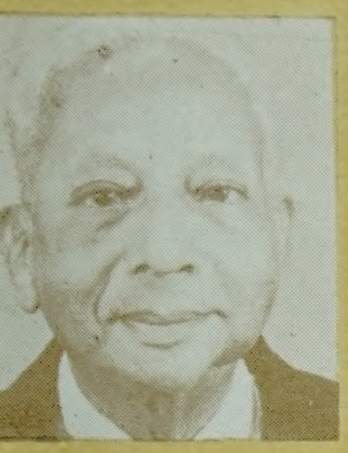

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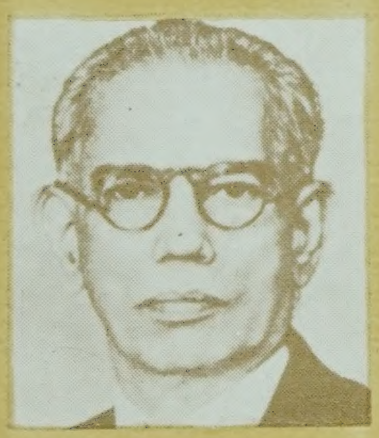
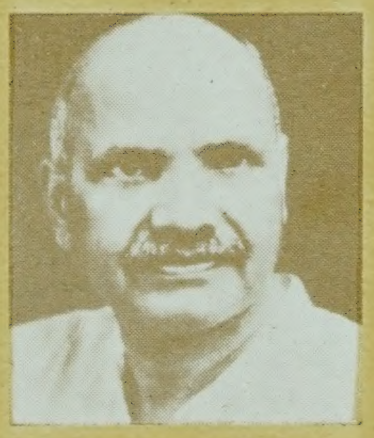

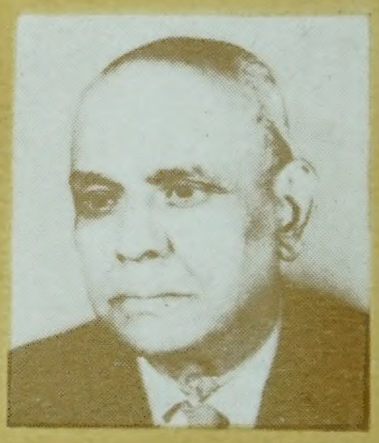

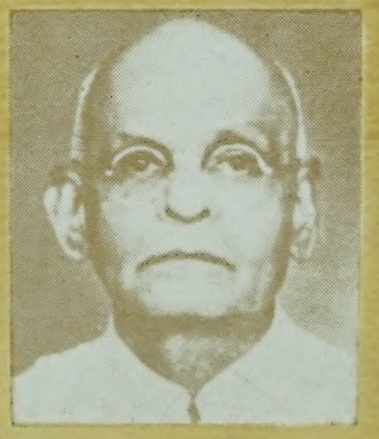

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Volume 7

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Volume 7

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PREFACE

THE present volume, seventh in the series of *Biographical Memoirs* includes the biographies of thirteen eminent Fellows who had carved a special place for themselves in diverse fields of biological, chemical, physical, mathematical and earth sciences. Time has swept away all of them, but the footsteps left behind by them are the launching pads for posterity.

Fermor had the distinction of being the first President of this Academy and the country owes immense debt to this unassuming Englishman who came to India with a missionary zeal to explore the vast mineral resources of the sub-continent. His three decades of service with the Geological Survey of India was productive and memorable. His distinctive contribution to mineral surveys speaks of his dedication.

S. L. Ajrekar, M. O. P. Iyengar, G. N. Rangaswami Ayyangar, S. L. Tandon, P. Parija and K. A. Chowdhury were all leading biologists. S. L. Ajrekar was in the Indian Education Service and served the Maharashtra Association for the Cultivation of Science with distinction. M. O. P. Iyengar made pioneering research in the field of algae built an excellent school of research and is rightly called 'Father of Indian Phycology.' G. N. Rangaswami Ayyangar's contribution to the improvement of millets is classical in the field of millet biology. P. Parija, besides being an eminent Plant Physiologist, was also a legendary figure in Indian Science in general and of Orissa in particular. K. A. Chowdhury's work in the field of Forest Science and Wood Anatomy gave a new dimension to the development of Forest products and the monographic series on Timber plants of India bear testimony to his outstanding contributions. His basic work made his name synonymous with 'Initial parenchyma.' S. L. Tandon was a cytogeneticist of repute. His work opened up many new lines of approaches in Botany and Agriculture specially in the field of endosperm cytology and floriculture.

Among the chemists is T. R. Seshadri under whose shade grew successive generations of scientists in dealing with Chemistry of Natural Products. Apart from his eminence in the field, his life was one of dedication to science to the point of self-negation.

The name of B. N. Prasad needs no introduction amongst the circle of mathematicians. He was the first Indian to receive doctorate from France in Mathematics and developed an active school in Modern Analysis. His pioneering contributions to several diverse areas of Advanced Mathematics as clear indices of his foresight and incisive thinking.

K. C. Sen was a distinguished physical chemist as well as a dairy expert and he was rightly called the Indian dairyman. He was largely instrumental for establishing the legitimate right of Animal Husbandry and Dairying in the overall agricultural planning in India.

The three distinguished Indian Physicists included in this volume are A. L. Narayan, S. N. Bose and D. M. Bose. Kodaikanal observatory and the Department of Physics at the Andhra University owe a great deal to the organisational ability of A. L. Narayan. He had the rare quality of fabricating equipments which helped him to design many original instruments for research, at a time when lack of such facilities was the greatest limitation for carrying out advanced research.

S. N. Bose was one of the eminent sons of India and a great humanist who brought glory to Indian Science in the international field. His originality was of such a high calibre that Albert Einstein translated one of his papers devoted to the derivation of Planck's Law and published it later referred to as Bose-Einstein Theory. Bose's contributions to Statistical Physics and Unified Theory justify to his genius and rare mental make-up.

D. M. Bose was a versatile and dynamic personality. Apart from his contributions to different aspects of theoretical physics, he extended Sir J. C. Bose's induction of stimulus in plant system. He was equally well known for his contributions in the field of History of Sciences in India and Science Journalism. The journal *Science and Culture* was nurtured by him and he remained its editor until his death. He had the vision and the unique ability of bridging the gap between the scientist and the common reader, and contributed immensely the popularization of science in India.

In many cases, it would not have been possible to obtain biographical information particularly on some of the distinguished Fellows without the ungruding cooperation from many sources and it is indeed a matter of great satisfaction that the memoirs have been written by eminent scientists, Fellows and others who were closely associated with the deceased scientist. I am confident that the material published in this volume will not only be of academic interest indicating the contributions of scientists who have been pace-setters in the development of science and technology in India, but will also be able to stimulate the readers to follow and emulate the examples of these great men of Science.

On behalf of the Academy, it is a privelege for me to express our gratitude to Professor B. R. Seshachar, a distinguished Fellow and former President of the Academy, for scrutinising the manuscripts at the initial stages. I am equally grateful to Professors H. Y. Mohan Ram and S. K. Trehan, the former Editors of Publications for examining the manuscripts and to Dr G. S. Venkataraman and Professor A. N. Mitra, the present Editors of Publications for finalising and successfully bringing out this volume.

I record my appreciation to Shri S. Rajan and Dr M. Dhara Assistant Executive Secretaries, J. Saketharaman Assistant Editor and to all the members of the Editorial Staff of the Academy for their valuable cooperation and ungrudging assistance during the preparation and production of this volume.

July 27, 1983

A. K. SHARMA
President

CONTENTS

Preface		v
Lewis Leigh Fermor	*S. Deb and W. D. West*	1
Shreepad Laxman Ajrekar	*T. S. Mahabale*	8
Mandayam Osuri Parthasarathy Iyengar	*T. S. Sadasivan*	12
Badri Nath Prasad	*S . R. Sinha*	22
Rao Bahadur Giyarpuram Nadathur Rangaswami Ayyangar	*N. Parthasarathy*	43
Appadvedula Lakshmi Narayan	*I. Ramakrishna Rao*	52
Satyendra Nath Bose	*S. D. Chatterjee*	59
Sohan Lal Tandon	*Umakant Sinha*	80
Debendra Mohan Bose	*S. D. Chatterjee*	86
Tiruvenkata Rajendra Seshadri	*S. Rangaswami*	102
Kshitish Chandra Sen	*S. N. Ray*	168
Pranakrushna Parija	*K. K. Nanda*	179
Kafil Ahmad Chowdhury	*A. K. M. Ghouse* and *Mohammad Iqbal*	188

A photograph and an autograph of the subject are printed with each memoir.

L. L. Fermor

SIR LEWIS LEIGH FERMOR

(First President of the Indian National Science Academy)

(1880–1954)

Foundation Fellow 1935

Sir Lewis Leigh Fermor was an Englishman who came to India imbued with great zeal and enthusiasm to explore the vast, hidden mineral resources of the Sub-continent. He dedicated his entire life and all his energies to the development of the mineral deposits of this country, and during the three decades of his service in the Geological Survey of India, he made outstanding contributions to the understanding and exploitation of the mineral wealth of this country. His interests were not confined to the economic aspects of a number of minerals and ores, significant as they were; he made distinctive contributions to academic areas of Indian Geology, such as the age of formation of minerals and rocks in the earth's crust and the Precambrian rocks of Peninsular India.

Fermor's versatility and breadth of vision were of phenomenal dimensions. He was a keen student of India's history and tradition. Her civilization, her sociological institutions, her cultural achievements and the wealth of her ancient literature fascinated him. He was not merely struck with India's scientific and technological advancement; he was deeply impressed by her intellectual attainments. His friendship with this country was genuine, deep and abiding, and long after he went back home after retirement, Fermor maintained his interest in India and her progress. He was greatly influenced in his thinking by the great scholars of his time—Rabindranath Tagore, Prafulla Chandra Ray, Brajendranath Seal and many others.

It was no wonder that this great scientist-scholar was chosen to be the First President of the Indian National Science Academy (National Institute of Sciences of India, as it was then known).

Birth and Education

Lewis Leigh Fermor was born in Peckham near London on September 18, 1880 to Lewis Fermor and Maria James. He had his schooling at the Wilson's Grammar School, Camberwell. He was later awarded a National Scholarship which enabled him to enter the Royal School of Mines in 1898, where he took a first class associateship in metallurgy in 1901. He was also the recipient of the *'Murchison Medal'* of the Royal School for his proficiency in Geology.

Fermor and the Geological Survey of India

Before completing the B.Sc. course, Fermor was persuaded by Professor J. W. Judd to apply for a post in the Geological Survey of India. A Committee headed by the late Dr W. T. Blanford, F. R. S., selected Fermor (along with the late Dr G. E. Pilgrim, F. R. S.), and he joined the survey as an Assistant Superintendent in 1902. Fermor's selection was fully justified subsequently by his outstanding researches in the various fields of earth sciences, particularly in analytical mineralogy, descriptive petrology, chemical analysis of rocks and minerals, and in the discovery of a number of new and unknown minerals. In the course of his long and highly productive career in India, Fermor dealt with almost all aspects of Indian Geology except palaeontology. This is evidenced by the mention of his name and achievements in almost all class-room teaching in India at under-graduate and post-graduate levels.

Fermor became Deputy Superintendent in the Geological Survey in 1904. Then during 1905–07, he was Curator of the geological collections of the Indian Museum and organised its mineral galleries. In 1910, he was promoted to the post of Superintending Geologist at the early age of 30. Between 1921 and 1930, Fermor officiated several times as the Director of the Survey, and he finally became its Director in 1930, succeeding Sir Edwin Pascoe. For the next five years he served as the permanent Director until he retired in 1935 at the age of 55. It was unfortunate that his period of office coincided with a period of financial stringency in India that forced upon him the unenviable task of retrenching several of the staff of his Department, though his unremitting advocacy of the value of a geological department to the prosperity of a country resulted in the partial restoration of the cadre before he retired.

Contributions to Indian Geology

The major interest of Fermor was in Archaean geology and in the different types of igneous and metamorphic rocks occurring in the different regions of India. His principal contribution was to the Precambrian rocks of Peninsular India, particularly in Madhya Pradesh and Maharashtra, with their rich mineral wealth.

Soon after his appointment to the Survey, Fermor was deputed by Sir Thomas Holland to report on the manganese-ores of the country. These ores had been worked since 1891, but little was known of their geology or mineralogy. The resulting *G. S. I. Memoir,* running to 1,294 pages, was published in 1909, and it was by this monumental work that he became best known outside India. It included not only an account of all the known deposits, with a discussion on their mode of origin, but also advice on methods of mining them, in which the pitch of the folded rocks was shown to be an important controlling factor. His field work had also brought to light several new manganese minerals.

Other economic minerals studied by Fermor included the Singhbhum and Sikkim copper deposits, the iron-ores of Ratnagiri and Goa, the Korea and Bokaro Coalfields, and the chromite deposits of Baluchistan and Orissa.

Of particular scientific interest was his paper entitled "Preliminary note on garnet as a geological barometer," published in 1913; for it led him to them

conception of an infra-plutonic zone in the earth's crust composed of eclogite, which he considered to be responsible for the explosive nature of deep-focus earthquakes by the exothermic change of garnet to less dense minerals, for isostatic adjustments in the earth's crust, and for the high fluidity of the lavas of fissure eruptions. His views on these matters were elaborated in a series of lectures that he delivered to the Indian Association for the Cultivation of Science as Ripon Professor for 1937, entitled "The role of garnet in nature."

After the completion of the memoir on manganese, Fermor was placed in charge of a party to carry out a systematic survey of the Archaean rocks of the Central Provinces, and he himself surveyed a tract of the country in the Sausar Tehsil, mapping the rocks in great detail, much of it on the scale of four inches to one mile. Begun in 1911, the work was interrupted by the 1914–18 World War, when his services were lent to the Railway Board in connection with the exploration of the Bokaro-Ramgarh Coalfields, and later placed at the disposal of the Indian Munitions Board. In recognition of this work, he was conferred an O.B.E. in 1919. After the War, the work in Central Provinces was resumed, and Fermor's own portion was completed in 1926. It is unfortunate that administrative and other duties prevented the full details of this fine piece of work from being published, though a summary of it was given in his later memoir on the correlation of the Archaean rocks of India.

Fermor's interest in the Deccan trap volcanic rocks began with a visit to Pavagarh hill, near Baroda, on which he published a note in 1906. Much later, in collaboration with C. S. Fox, he mapped the lava flows of Linga, near Chhindwara, showing them to have been considerably disturbed. He reverted to this subject in a paper entitled "On the chemical composition of the Deccan trap flows of Linga, Chhindwara District, Central Provinces" published in 1934. But before this, he had studied in 1925 the cores obtained from a deep boring put down through the Deccan trap lavas at Bhusawal, paying particular attention to the secondary constituents of the flows. Finally, before he retired from the Geological Survey of India, he began writing a memoir the title of which was "An attempt at the correlation of the ancient schistose formations of Peninsular India." After giving a general discussion on the factors to be considered in effecting a correlation, he had planned to give a summarized account of the geology of the various Archaean provinces into which he divided India and Burma. A final section was to have been devoted to an attempt to correlate the rocks of the various provinces, if at all possible. Of this plan, only the general discussion and the account of less then half the provinces had been published by 1940, and other commitments prevented the completion of further sections before his death. Thus a work that woud have been of the greatest value to geologists in India was left largely uncompleted.

Fermor and the Indian National Science Academy

The Indian National Science Academy owes a great deal to Fermor as he was the first President of the Academy known at that time as the 'National Institute of Sciences of India.' The inauguration of the Academy was held on January 7, 1935, when Fermor delivered his Presidential Address on the organisation of scientific

research in India. The Address in the beginning deals with the development of science in Europe, particularly with the birth of Science during the Golden Age of Greece in the period between 450 and 400 B.C. It traces next the history of developments which took place during the renaissance in Europe in the 13th to the 16th Century A.D. leading to the foundation of the Royal Society of London in 1660 and the Academic Royale des Sciences in France in 1666. In his Address, Fermor also referred to the foundation of the Asiatic Society in Calcutta by Sir William Jones in the year 1783, for studying the antiquities, arts, sciences and literature of Asia. While mentioning the establishment of the Trigonometrical Survey of India in 1800, which is now the geodetic branch of the Survey of India, the establishment of the Geological Survey of India in 1851 and that of the Bombay Natural History Society and the Indian Association for the Cultivation of Science in Calcutta around 1883, Sir Lewis pointed out that there was an urgent need for the coordination of official scientific enquiry.

Sir Lewis felt the need for encouraging scientific researches in India through an Academy which should maintain a liaison among scientific academies and should yublish regularly papers in its *Proceedings*. He also envisaged an annual review of the Progress of Science in India. Sir Lewis also emphasised the need for the organisation of symposia, seminars, conferences, lectures, etc., by the Academy which might ultimately turn into a reservoir of scientific knowledge.

The first Anniversary Address of the Academy was delivered by Sir Lewis in 1936, at its meeting held at Indore, where he described the methods used in the correlation of the Archaean rocks of India. He referred to the two sub-divisions of the Pre-Cambrian rocks, Puranas and Archaeans (classified by Sir Thomas Holland) and pointed out that the Puranas were free from the effects of batholithic igneous intrusions whereas the older Archaeans were often intruded by batholithic granites along with aplites, pegmatites and quartz veins. Fermor also mentioned that some of the important epigenetic ore deposits had been associated with the Archaeans such as the auriferous deposits of Karnataka, copper deposits of Singhbhum, Sikkim, etc. He was of the opinion that the Gondite series of rocks are metamorphic rocks formed by the metamorphism of manganiferous sediments of varying degrees of purity.

While concluding the Address, Sir Lewis mentioned that geologists did not practise a science enclosed in a water-tight compartment. At every step, geologists had to be dependent upon other sciences. He felt that the assistance given by the geological sciences to the other scientific disciplines was particularly emphasised in the fact that the fossils discovered during stratigraphical researches have provided enough materials of fundamental importance to support the theory of evolution of life upon the earth.

His Role for the Advancement of Science in India

Fermor played a very important role for the advancement of science in India. The late Professor M. N. Saha, F.R.S., F.N.A. used to admire him for his ability and efficiency in organising scientific researches in India. Fermor was gifted with an ability of taking enormous pains with patience in going into the details of any

complex problem given to him for study. He trained the young Officers of the Geological Survey with sympathy and they in turn used to respect him as their teacher and guide. He was, however, a hard task-master but at the same time very considerate. A Geological Club in his Department was started by Fermor in order to enable young officers to debate on the particular problems which they faced, and to get the considered opinions of other colleagues.

Honours and Distinctions

For his original ideas on garnet, eclogite and an infra-plutonic zone, perhaps his most original contribution to geology, Fermor was awarded the *'Bigsby Medal'* of the Geological Society, London in 1921. He was elected a Fellow of the Royal Society in 1934, and was the first recipient of the *'P. N. Bose Medal'* of the Asiatic Society of Bengal in 1944. On the eve of his retirement in 1935, he was made a Knight Bachelor.

Fermor took an active part in the work of many societies. In addition to being the first President of the National Institute of Sciences of India (now the Indian National Science Academy) in 1935, he had been President of the Mining and Geological Institute of India in 1922; of the Asiatic Society of Bengal in 1933; of the Indian Science Congress Association in the same year; and of the Institute of Mining and Metallurgy, London in 1951, his Presidential Address on that occasion being on "The mineral resources of Gondwanaland."

After Retirement

After his retirement from India, Sir Lewis worked as a consulting economic geologist in South Africa, Malaya and in several countries of Asia. In 1938, he came to India as a delegate from the British Association for the Advancement of Science to the Silver Jubilee Celebration of the Indian Science Congress. He once again came to India in 1951 during the Centenary Celebration of the G.S.I., when one of the present authors had the opportunity of meeting him in Calcutta. The author happened to show Fermor an electric bulb manufacturing factory near Jadavpur. Fermor was unhappy to hear that tungsten filaments for lamps were imported from abroad, instead of utilising the tungsten ore from the Bankura District, West Bengal.

Personal Life

Fermor had married Muriel Ambler in 1909 and had one son and daughter by this marriage. In 1933, he again married Frances Mary who survives him.

During the Second World War Fermor went to Bristol and stayed there for a few years, but later on moved to Woking, in Surrey, where he named his house 'Gondwana.'

Fermor left this world on May 20, 1954 at Woking after serving the cause of Earth Sciences for several decades. The affection and sympathy he cherished as the first President of the Indian National Science Academy continued till his last

days. He has left a prominent landmark in the history of Indian Geology for the benefit of the young Indian geologists which cannot be forgotten, and he will be remembered with great respect and honour.

S. DEB*
W. D. WEST

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*Since passed away

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SHREEPAD LAXMAN AJREKAR

(1883–1954)

Foundation Fellow 1935

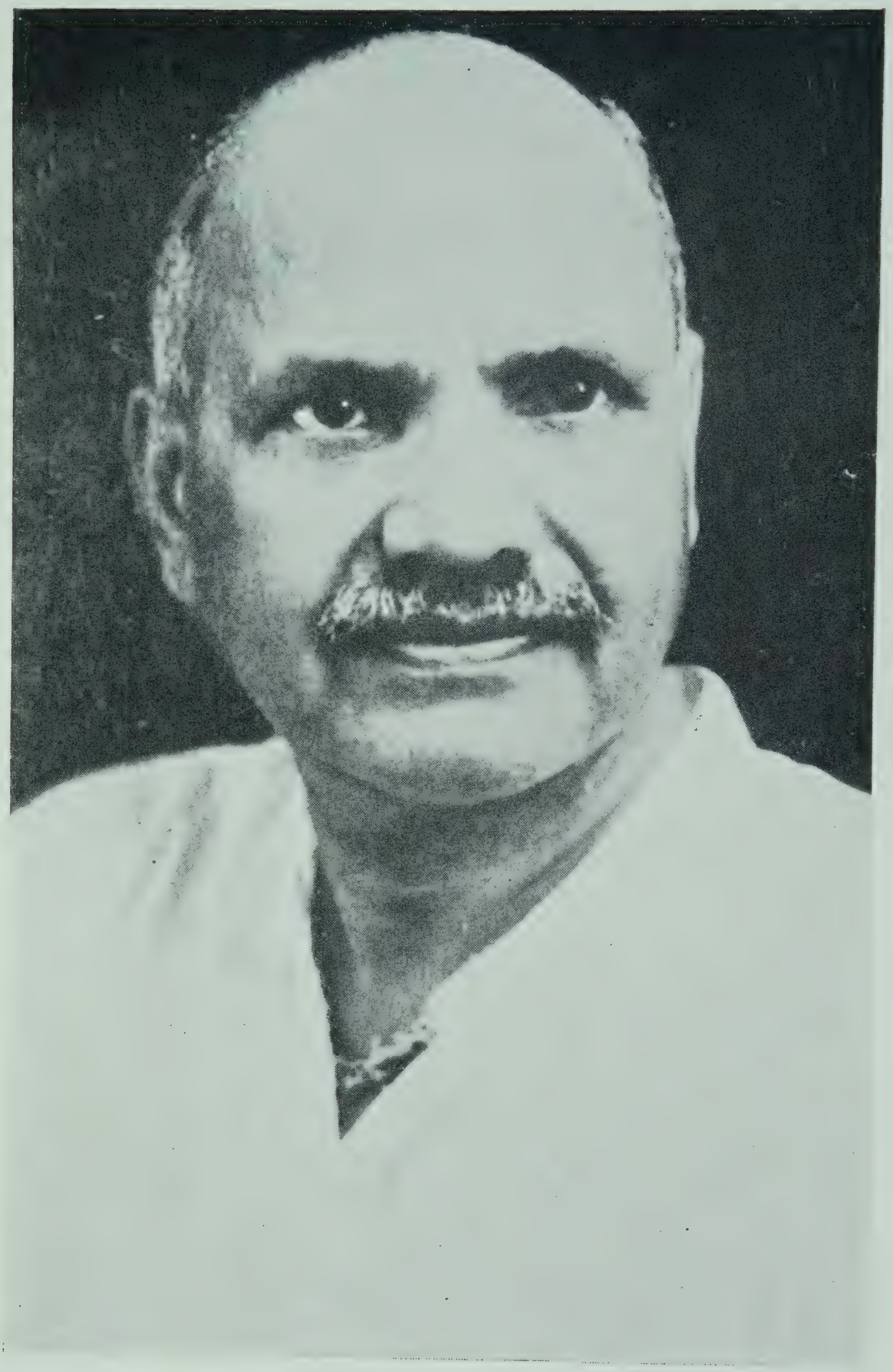
Birth and Early Education

Shreepad Laxman Ajrekar was born on March 28, 1883, at Ajra, a small tehsil in Kolhapur district. His early education was under the supervision of his father who was a school master at Ajra. For his secondary education, he went to Belgaum and joined the Sardar's High School, where he took his matriculation examination very creditably. He then shifted to Bombay and joined the Wilson College and took his B.A. degree of the Bombay University in 1903 with honours and merit, with Botany and Zoology as his special subjects.

Higher Education and Career

Ajrekar's ambition to get trained in biological sciences abroad was fulfilled when he was awarded the *Sir Mangaldas Nathubhai Scholarship* of the Bombay University in 1905. One of the conditions attached to this scholarship was that the selected candidate was to undergo technical education in Britain. This scholarship took him to the Mycology school of the Cambridge University that was established by the distinguished mycologist, Marshall Ward. Ajrekar obtained the Diploma in Agriculture in 1907 and the B. A. Hons. degree in 1908 with botany, chemistry and geology. On his return to India, Ajrekar was appointed Assistant Professor of Mycology at the College of Agriculture, Pune, in December 1909. He also acted as Economic Botanist to the Government of Bombay during 1917–19. He was promoted to the Indian Agricultural Service in May 1920 and appointed as Mycologist to the Government of Central Provinces, at Nagpur. He was again transferred to Bombay Province as Plant Pathologist to the Government of Bombay, in December 1920. Being essentially interested in applied and fundamental aspects of science and education, he was transferred to the Indian Educational Service in January 1923. He worked as Professor of Botany at the then Royal Institute of Science, Bombay (now Institute of Science, Bombay). Later, he was transferred to the Science Institute at the Gujarat College, Ahmedabad. He retired from the I.E.S. in March 1938.

Professor Ajrekar's early predilection was for an academic career, teaching pure and applied science. Thus, the post of Professor of Botany at the Royal Institute of Science, Bombay was very much to his liking and he worked here from 1923 to 1928.



S. L. Aziz

At that time, the Science Institute at the Gujarat College, Ahmedabad was newly started and was getting organised. It was necessary to have a scholar of repute and an experienced man for the teaching of Botany at that Institute. Thus, he became the Professor of Botany at the Gujarat College, Ahmedabad.

His Wide Knowledge and Versatility

Professor Ajrekar was known for his wide knowledge and its application to various problems of research especially in fungi. His papers on plant diseases give ample evidence of a highly critical mind. They have been published in reputed Indian as well as foreign journals. In recognition of his services towards the advancement of science, several academic honours were conferred upon him. He was President of the Indian Botanical Society and also its Founder member. He worked on the editorial staff of the *Journal of the Indian Botanical Society* and was a Fellow of many scientific institutions in this country like the National Institute of Sciences of India (now the Indian National Science Academy, New Delhi), Bombay University etc. He took active interest in the teaching Botany and Agriculture at the Bombay University. He was on several Committees and Boards of Studies in Botany and Agriculture in that University. In 1927, the Andhra University invited him to be a member of the Board of Studies in Natural Sciences, to benefit from his long experience in education. He continued to work on it even after his retirement. While at the Agricultural College at Pune and at Gujarat College, he had multifarious duties, which left little time for personal research in agriculture, mycology, or in education. The leaders of various trade unions and institutions used to seek his advice. His writings had precision and brevity and had a stamp of his personality. His teaching also was very exact. His papers on plant diseases in English or Marathi were deeply appreciated by the public. In a Marathi Encyclopaedia "*Dnyankosh*" edited by Dr S. V. Ketkar, he wrote several articles on Plant Life. He was a founder member and promoter of the scientific Marathi monthly, "*Srishtidnyan*," for which he wrote a series of articles on plant diseases to popularise the science of mycology and plant pathology. He also wrote a very interesting book in Marathi, called "*Vanaspati Jeevan*," which became quite popular with general readers. In Bombay, at Ahmedabad and even after his retirement at Pune, he guided post-graduate students in research at the Fergusson College, Pune and in the Botany Laboratory of the Maharashtra Association for the Cultivation of Science. Several of his students attained distinction, both as scientists and teachers. As a member of the Committee and Council of the Deccan Agricultural Association, he was very useful. The Tilak Vidyapeeth appointed him for a review of scientific literature in Marathi. He looked at all questions whether of science, teaching of society from a national point of view. His paper on "*Cotton Wilt*" and his Presidential address to the Indian Botanical Society in 1927 are examples of his objectivity.

A Rebel and a Reformer Educationist

Professor Ajrekar strove for equality and parity for the Indian members of the Indian Educational Service with their European counterparts with regard to status, pay and

other facilities. In the beginning, as expected he was not successful. He made a strong representation to the Royal Commission of Indian Services presided over by Lord Islington who considered it as a major contribution for change, in the policy of Indianization of I.E.S. and other Imperial services. It opened I.E.S. and the other services to Indians on equal terms and appointments to various posts were made without any discrimination for Europeans. His sense of nationalism and nationality was annoying to the authorities. He was transferred from the Agriculture to the Education Department. Even here, he took cudgels against authoritarianism and unjust treatment given to Indians. Because of this, he was never appointed Principal of the Gujarat College, although it was due to him by virtue of his seniority in the I.E.S. He, however, never regretted, but felt satisfied that he was of service to his countrymen in getting the service rules changed. For a very short period, he acted as Principal of the College of Agriculture, Pune.

A Selfless Individual

By temperament, he would have preferred to work in a quiet manner devoted to teaching and research in Plant Sciences. In those days, the Freedom Movement was on. He thought that everyone in office should do something in his capacity to assist it. He had no particular faith in God, but he believed in the general manifestation of some sort of directive power, inherent in all natural phenomena. He was a non-believer in *Punarjanma* or the survival of the soul after death and rebirth. But he never made any show of these beliefs. He was mainly a follower of the teachings of the *Bhagawad Gita* and its message of conscious performance of one's duty and indifference to success or failure. He was the embodiment of selfless behaviour. To him these were not mere beliefs, but practical working rules from which excellent results followed for both the individual and the society, of which he was a member. He felt that selfless service in life made a man happy. Because of his theories, he had a profound influence on many members of different sects. Even a revolutionary such as Senapati Pandurang Mahadeo Bapat, believed in his advice.

A Mycologist of Reputation

His work on cotton wilt, Mucor, *Aspergillus* and Potato rot is considered standard by all mycologists. He had many distinguished pupils and colleagues like the late Dr M. N. Kamat, Professor S. A. Parandelkar, Shri Murthy, Dr V. P. Damle, Shri V. M. Ghatge, Shri Dharmarajulu, Dr P. S. Gharse, trained in research and techniques under his guidance. His associates and pupils had a very high regard for him. To honour the memory of this distinguished mycologist, the *Ajrekar Mycological Herbarium* has been established at the Maharashtra Association for the Cultivation of Science at Pune. The type materials at this Herbarium are exchanged with other world Herbaria such as the Commonwealth Mycological Institute, England, Indian Agricultural Research Institute, New Delhi, P.U.R., U.S.A., I.B.G., England and with several other bodies.

He was the real architect of the Mycology and Plant Pathology Department at the Maharashtra Association for Cultivation of Science, (M.A.C.S.) which itself is a tribute to this distinguished Mycologist.

T. S. MAHABALE*

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NOTE: Besides these he has published more than 20 papes in Marathi in *Srishidnyan* and other scientific periodicals and a book on "*The Life of Plants*" (वनस्पति जीवन).

*Since deceased.

MANDAYAM OSURI PARTHASARATHY IYENGAR

(1886–1963)

Foundation Fellow 1935

Mandayam Osuri Parthasarathy Iyengar born on December 15, 1886 in Madras had an impressive lineage of judges, teachers, scientists and industrialists. He was the fifth of the eight children of M. O. Alasingaracharya, a well-known solicitor of the Madras High Court and Alamelu Ammal who hailed from the ancient temple town of Melkote, Karnataka State.

Early Life, Education and Teaching Career

Matriculating from the Hindu High School, Triplicane, Madras, young Parthasarathy joined the Presidency College in 1901 and graduated in 1906. In 1909, he took his M. A. Degree in Botany from the same institution. He was proud of being a 'Presidencian.' The young 'MOP' or 'Pacha' (as he was known to his contemporaries) was a distinguished sportsman in his college days, notably in football. He was also fond of indoor games and, in later life, he developed an interest in billiards and became an amateur champion of the South. Club life attracted him, though only for relaxation and recreation as he strictly refrained from gossip and politics of any kind. He led a disciplined life, which he continued to maintain right up to the end. He was a non-smoker and a strict vegetarian. Coffee was his only weakness and in his home, a giant-sized silver tumbler of this beverage gave him all the satisfaction in the world.

Soon after taking his Master's Degree in 1909, Iyengar joined Government Service as Curator in Botany at the Madras Museum. In 1911, he left this position to enter the Madras Educational Service as Head of the Teaching of Natural Science in the Teacher's College in Madras. Amongst the first things he did there was to revise the curriculum of teaching and evolve a new system of teaching Natural Science within the classical framework.

In less than a decade, Iyengar rose to the rank of Professor of Botany and was posted to his old *alma mater*, the Presidency College, Madras, and remained there from 1920 to 1933. Those were the years when a galaxy of British and Indian educators worked together to make the Presidency College one of the foremost post-graduate institutions affiliated to the University of Madras. Professor Iyengar's association with botanists like Professor P. F. Fyson (who later became Principal of the Presidency College) made the Department a renowned centre of learning in Botany.

M. S. Iyengar

Iyengar : the Teacher

During this period of thirteen years at the Presidency College, a new chapter had opened in Professor Iyengar's academic career. His reputation as a great teacher in the classroom was established. The present author can vouch for this as he graduated during that period (1930–34). Students loved, respected and feared him.

Professor Iyengar at first appeared to have been uncertain of the discipline in botany he was ultimately to choose for research (evident from his early papers in such diverse fields as Phenology, Teratology and Angiosperm Ecology). But soon he developed an interest in Algae, which remained his area of specialization and research all his life. Professor Iyengar steadily built up a research tradition in algae. The Presidency College, Madras, became the country's foremost centre for research in algae under his stewardship. Indeed, his interest in algae dates as far back as 1909, when he submitted his first dissertation paper on the group for his Master's degree.

Prefessor Iyengar was elected President of the Botany Section of the Indian Science Congress and his address to the 1928 Session of the Congress bears the stamp of scholarship and creativity of a keen research mind. The address reviewed the algal work done in India and presented the contributions to systematics, ecology, phyto-plankton studies, algal associations, geographical distribution, cytology, handling of type specimens and finally, problems of teaching algology in the University. His anxiety at that time was to employ Indian examples. He used to say that it was his dream to have a text book of botany for India giving life-histories of Indian plants.

In 1928, the famous Danish Algologist, Dr F. Boergesen, visited this country and together, Iyengar and Boergesen collected and studied marine algae on the Coromandel coast and later in the coastal areas of some parts of Ceylon (now Sri Lanka). This was a landmark in the Professor's career as the rich collections made during these field trips formed the cornerstone of the algal school he was to build later at the University of Madras.

Iyengar : Teacher of Teachers

Looking back to my student days at the Presidency College, Madras, in the early thirties, I cannot but admire the galaxy of academic men in all disciplines of the humanities and sciences. Among the 'tallest' was Professor M. O. P. Iyengar. One cannot forget those impressionable years when men of stature guided, effortlessly as it were, the destinies of so many of their wards in the fond hope that in the not too distant future they would take their places in key academic positions in the country. That was the only reward they looked for.

While Professor Iyengar's lectures were a delight, well illustrated, logical and sequential, his practical classes were even more so. Professor Iyengar believed in the maxim : *What you cannot see, you need not believe.* *Śraddhā* was the key-word, a mental attitude constituted primarily of sincerity of purpose, humility reverence and faith.

Many years later, the present writer happened to take a distinguished Chemist to Professor Iyengar when the latter was keenly examining some new collections of diatoms and desmids under the microscope. The *Śraddhā* attitude which he inculcated in us was evident then, as it was twenty years ago. My chemist friend peered through the microscope and asked : "Tell me, Iyengar, why are these organisms so symmetrical in their structure." Being a lover of nature and an admirer of its architectural symmetry, he quipped, "Tell me 'why not,' and I will tell you 'why'."

The atmosphere in the educational institutions in the country then was relatively placid. While the top teaching positions in the Colleges and Universities were held by British Professors, it was clear that their Indian colleagues often outshone them. Recognition, however, was slow and many Indian intellectuals failed to obtain the recognition, they deserved. Research facilities hardly existed in the sciences and efforts to build them were not encouraged. Higher learning was available only in a few Universities and even to obtain a Master's degree, one had to move to another University. Doctoral programmes did not exist even in these Universities and the British Professors themselves did not, in most cases, possess doctorate degrees. One, therefore, had to go abroad, usually to Britain, to obtain a doctorate degree. It was under these circumstances, Professor Iyengar proceeded to Britain, having been fortunate in obtaining a placement to work with the celebrated algologist Professor F. E. Fritsch.

Exposure to Western Science

The years that followed in Professor Fritsch's laboratory at the Queen Mary College, University of London, were memorable for Professor Iyengar. He was awarded the Ph.D. Degree of the London University in 1932. More than an exposure to Western science, Iyengar's stay at the Queen Mary College, which was a Mecca for algologists was eventful in forging strong links between Indian Botany and that of Britain. Professor Iyengar often used to refer in reverential terms what appeared to be the fortuitous circumstances under which he walked into Fritsch's laboratory in London and his gratefulness to Providence. Indeed, life started for Iyengar after forty !

Return to India

Professor Iyengar returned to the Presidency College in 1932 and remained there for hardly a year before moving to the newly created research chair of Botany at the University of Madras. It was not just a matter of changing places. As Iyengar rightly visualized, the new research chair at the university opened up a whole vista of research opportunities which he employed to establish a school of research in algology. Professor Iyengar's hard work and devotion had earned for him not only his pre-eminent position in algology, but also the goodwill, understanding and co-operation from eminent contemporary botanists like Professors B. Sahni, P. Parija, and S. P. Agharkar.

Distinguished Research Director

The association with Professor Fritsch was intellectually the most stimulating experience in Iyengar's life and in token of its acknowledgement, he erected the now well-known genus *Fritschiella.* Iyengar was appointed Director, University Botany Laboratory (UBL) in Madras in 1933, a position he held with great distinction till 1944. A steady stream of scientific papers, on several aspects of algal research, flowed out. Modest to a fault, Professor Iyengar believed in no fanfare; he gave his best to the research scholars who crowded around him. Many bright careers were built there and the algal tradition became firmly established. Meticulous in whatever he did, the Professor was an example to younger men. Algal research was for Professor Iyengar, his very life breath and he believed in research for research's sake. His specialization in algae did not, however, cloud his vision and his deep appreciation of other disciplines of plant sciences led to an all-round development of botany in the University. Indeed, he was sincerely committed to the growth of all sciences in the country. Sincerity of purpose, an even temperament and a philosophical outlook were the hallmarks of this eminent scientist.

Professor Iyengar did not believe in frequent curricular changes in the University. Indeed staid, and with a rather conservative outlook on aspects of higher education, he would quietly observe that fashion subjects would come and go, but classical botany would survive.

Iyengar : The Man of Science

Professor Iyengar's main forté was collection of algae from far and wide and their examination. Collections came to him from all over the world. He described many new species and with his pupils erected a number of new genera typical of tropical situations. One must add here that only a part of his enormous research material was published.

Professor Iyengar's chief contribution to the origin and evolution of plant life was in the creation of the genus *Fritschiella.* Bower, in his classical book, *"Primitive Land Plants"* has given a special status to this genus in the Chapter dealing with Prothallus and Gametangia : *"Interest in 'Fritschiella tuberosa 'lies in the terrestrial habit, and in the fact that this amphibial plant possesses the essentials of a three-dimensional, photosynthetic sub-aerial thallus originating from a simple filament. In 'Fritschiella', the crude materials are present for the organization of a higher vegetative development on land, such as the Archegoniatae possess. What is lacking in the gametophyte of these green terrestrial algae is further massive development and localization of growth. It is upon these factors that evolution of the haploid phase in the Archegoniatae has been mainly founded."* In short, Bower considered this alga as occupying a special position in understanding the origin of land plants.

Immense as Professor Iyengar's research was to life-history, cytology and distribution of algae, his most important contribution to Indian algology was in the area of algal ecology as a dynamic discipline. Man's awareness of the biosphere is only a decade or two old and today there is a scramble to get on to the 'environmental ecology/pollution' bandwagon. Way back in the twenties, Professor Iyengar, in

his quiet way, laid the foundation for these studies. His Presidential Address to the Botany Section of the Indian Science Congress in 1928 and the Symposium he ledin the Silver Jubilee Session of the Science Congress in Calcutta in 1938 bear testimony to the farsightedness and leadership of the Professor.

Quite obviously, Professor Iyengar was a pioneer in the study of lakes and large bodies of water. Algal floras of temporary waters and their succession, algal blooms, paddy-field algae, algae of estuarine regions, algae in relation to aquatic animals, all these occupied his attention. Professor Fritsch, who was physically present at the 1938 Calcutta Symposium said in his concluding remarks : *"Mere description of species until such species were known to be of ecological value, was scarcely the best way of utilizing the abundant energy of the numerous workers on Indian Freshwater Algae. How great a contribution Indian algologists can make to our knowledge of algal morphology is abundantly illustrated by Iyengar's work on Tetrasporidium, Ecballocystis, Characiosiphon etc."*

It underlines, once again, the great significance of new areas of human endeavour; not all are fortunate to carve out a position for themselves in the scientific history of a developing country. Professor Iyengar did unquestionably. With meagre resources, few students and marginal encouragement from the administration, he possessed the courage to defy adverse circumstances.

Modern scientific research appears to demand sophisticated and expensive equipment, and while in several areas of Science, including Biology, it is true to say that much recent advance has been due to the employment of such instruments, there are disciplines which call for ingenuity rather than enormous inputs, where observation and creativity will further the advance of knowledge. Iyengar was an example of a scientist who, with meagre equipment but with hard work and dedication, made highly significant contributions to the expansion of our knowledge in plant sciences.

Distinctions

Professor Iyengar was a member/fellow of many learned Societies : Fellow of the Linnaean Society of London, Fellow of the American Association for Advancement of Science, Foundation Fellow of the Indian Academy of Sciences and the Indian National Science Academy (formerly known as the National Institute of Sciences of India); President, Botany Section, Indian Science Congress, 1928. He was one of the Founders of the Indian Botanical Society and was Editor of its journal—*Journal of the Indian Botanical Society*. In token thereof, Professor Iyengar was presented a Commemoration Volume in 1947 at the University of Allahabad at a special annual session. It was edited by Professor B. Sahni and contained articles by many leading botanists from India and abroad. Professor F. O. Bower, at the age of ninety, sent an article and mentioned that this was his last scientific writing and he did so for a Festschrift to honour his friend Iyengar!

Professor Iyengar was the first recipient of the *Birbal Sahni Medal* of the Indian Botanical Society and the first recipient of the *Sundar Lal Hora Medal* of the Indian National Science Academy. At the time of his death, he was President of the International Phycological Society and the Phycological Society of India. Professor Iyengar was elected Honorary President of the 8th International Botanical Congress, Paris in 1954—an honour he highly valued.

Iyengar : The Man

A memoir on Professor Iyengar would be incomplete without reference to his qualities as a teacher and friend. Professor Iyengar bore no ill will towards anyone—a rare human trait. In fact, he never discussed personalities, although he often related some reminiscences packed with humour. He was intensely warm, affectionate and cheerful and he did not hesitate cracking a joke at himself. Nonetheless, he took life seriously and uppermost in his mind, at all times, was motivation. Little wonder that he was a perfectionist.

The present writer's long association with this eminent scientist sharpened his admiration for the professor. Iyengar was a man of genuine humility and his affection for his students was legendary. The author still recalls with gratitude how he was quietly visited unannounced by Iyengar when the former succeeded him at the UBL in 1944. The scene is vividly before the author. When he stood up to greet him, he (Iyenger) gently pushed him back into his seat and said : "I have come to see you occupy this 'Chair'." This was followed by a warm handshake. No words passed between them for a few minutes—a silent approbation of the mantle that he had passed on to one of his pupils. That was the revered *"Guru"*—the celebrated Iyengar, a *Purushottama* !

Family Life

Professor Iyengar headed a large and happy family of five sons and a daughter. A firm believer in the benefits of the joint family system, he had all his sons living with him. Only one of his sons did Biology and even he went into business after graduation. One other son was a well-known cricketer.

Professor Iyengar's wife Srimathi Janaki Ammal was a person of high culture, brought up in the highest traditions of a religious Vaishnavaite family of Mysore. Together, they made a hospitable couple and their ancestral home in Triplicane (Madras), was an open house for friends and students. Srimathi Janaki Ammal predeceased Professor Iyengar and he was, for the rest of his life, a lonely man but with a poise of a *Karma Yogi* immersed in his World of Algae.'

Professor's Last Days

Professor Iyengar died on the December 10, 1963, after an attack of cerebral thrombosis. He spent the morning of December 6 working with the microscope and appeared to have made some *Camera lucida* drawings with a firm hand. A life of contentment, lived with dignity, beyond the biblical age of 'Three score and ten' reached its end reminding us of Alexander Pope's famous lines :

"Happy the man, whose wish and care
A few paternal acres bound,
Content to breathe his native air,
in his own ground."

On December 6, 1963, the Professor had his lunch as usual, around midday. The fateful attack followed soon after and he went into a coma. He had more than once mentioned to the writer that he would like to pass away on an *Ekadasi* day considered appropriate for a devout Hindu; December 10, 1963 was *Ekadasi* ! Born in Triplicane, Madras, he lived for 77 years in the same place and his mortal remains were returned to the elements right there. This was appropriate for he loved his surroundings, the Madras marina and the sea, which he could see from his working-cum-living room on the first floor of his home.

Perhaps a personal note may not be out of place and might be forgiven. The writer was one of Professor Iyengar's early pupils, and it became his privilege to succeed him as Head of the University Botany Laboratory in 1944. The greatest aim which the writer had on that occasion was to maintain the rich and valuable traditions Professor Iyengar established in research in Plant Sciences. Whatever the results achieved, it could be honestly said that no efforts were spared in trying to make the Madras University Botany Laboratory one of the outstanding centres of research in the country.

Acknowledgement

The author has benefited by consulting obituaries on Professor Iyengar written by several algologists : Professor T. V. Desikachary, Professor M. S. Balakrishnan, Dr M. S. Randhawa, Shri K. R. Ramanathan and Dr R. Subrahmanyan. Also much help has been received from Professor V. S. Sundaralingam. The author's thanks are due to them.

T. S. Sadasivan

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Note : The publications of Professor M. O. P. Iyengar from 1968 were posthumously edited and published by Professor T. V. Desikachary, FNA.

BADRI NATH PRASAD

(1899–1966)

Elected Fellow 1936

Childhood and Formative Influences

Born on January 12, 1899, of a well-known respectable family of businessmen of Mohammadabad-Gohna in the Azamgarh District of the State of Uttar Pradesh in India, Badri Nath Prasad was the youngest son of his parents. A man of foresight and practical wisdom, his father, Sri Ram Lal, succeeded in giving the best possible education to his sons. Full of promise in his boyhood, young Prasad had a remarkably strong memory. He used to recall, how in his school days he could perform the amazing feat of memorizing even long verses by reading them only once or twice. In shaping his personality, his mother and elder brother seem to have exercised an influence even greater than his father did. With a feeling of reverence, he used to recall how on every occasion he paid his obeisance to his mother, who blessed him, "Go, Be Victorious."

School and University Education

Young Prasad started his early education by learning the Urdu language, but later on he switched over to Hindi, thereby obtaining an almost equal command over both the languages. Early in his school career he studied in his home town Mohammadabad-Gohna and the C. A. V. High School of Allahabad (with his elder brother who was then studying in the Allahabad University), and passed the Matriculation Examination of the Calcutta University from the V. M. H. E. School, Siwan (Bihar), and the I. Sc. and B. Sc. examinations of the same University from the Patna College, Patna, with a uniformly brilliant record. During these years he was particularly fond of playing hockey. For his M. Sc. degree in Mathematics, Prasad studied at the Banaras Hindu University and obtained a first class first both in the Previous and Final year examinations in 1920 and 1921 respectively securing a higher percentage of marks than any other candidate.

Influence of Dr Ganesh Prasad

While studying for his M. Sc. degree, B. N. Prasad came in close contact with his teacher Dr Ganesh Prasad, who, recognizing his talents, inspired him to take to teaching and creative research in Pure Mathematics. In those days, desire to join the Civil Services was almost a craze among bright Indian students. On the basis

B. N. Prasad

of his brilliant result in the M. Sc. examination, Prasad was actually offered a lucrative assignment. Members of his family urged him to accept this offer, but he declined it and out of love for Mathematics and reverence for his teacher and followed Dr Ganesh Prasad's advice. Such was the loving influence of this great teacher on his pupils. So, in July 1921, B. N. Prasad got himself enrolled as a research scholar in the Department of Mathematics of the Banaras Hindu University to work under the supervision of Dr Ganesh Prasad. His appointment was that of an Assistant Professor of Mathematics and this made him shoulder a heavy teaching load, but Prasad's zeal and interest in advanced topics were so great that he published two original papers on the properties of non-differentiable functions. Dr Ganesh Prasad moved to the Calcutta University in 1923, and B. N. Prasad joined the Allahabad University on July 17, 1924 as a Lecturer in Mathematics. A number of his good students migrated with him to Allahabad.

Research Career Abroad

As a young lecturer B. N. Prasad had to shoulder a heavy teaching load at Allahabad also and this retarded the progress of his research work to some extent. But during the first five years he spent at Allahabad, he devoted himself to an intensive study of the work of eminent mathematicians of Europe and England, like W. H. Young, G. H. Hardy, J. E. Littlewood, E. C. Titchmarsh, H. Lebesgue, A. Denjoy and others on the theory of trigonometric series. Their work fascinated him so much that B. N. Prasad obtained study leave from the Allahabad University and proceeded in 1929 to the United Kingdom. Initially, he stayed for a few months at Edinburgh and did some work on the theory of Fourier series, but thereafter went to Liverpool to work with Professor E. C. Titchmarsh. He completed his thesis for the Ph. D. degree of the University of Liverpool in 1931. Highly impressed by his work, Professor Titchmarsh, writing about Prasad, said : *"I found him an extremely industrious and intelligent worker who had plenty of ideas of his own and merely asked for my advice and direction."*

After completing his Ph. D. thesis at Liverpool, B. N. Prasad went to Paris to work with the famous French mathematician Arnaud Denjoy. Under the guidance of Professor Denjoy, Prasad prepared in less than a year his well-known thesis entitled : *Contribution a l' étude de la séries conjuguée d'une série de Fourier.* This thesis earned him the degree of *Docteur ès Science* of the University of Paris with mention *très honorable.* The *'soutenance'* of his thesis for the *doétrat d'Etat* took place on June 4, 1932, before a Jury consisting of Professor Emile Borel as President and Professor A. Denjoy and Professor G. Valiron as examiners. The quality of his thesis greatly impressed the examine and Professor Borel, while announcing the result, paid compliment to Prasad, saying (*translation*):

"You have shown particular merit in writing your thesis in French language and in showing proof, in its defence, of a very deep knowledge of our language. We know that a magnificent development of science, and articularly of mathematical science, has taken place in your great and beautiful country. We can only rejoice to see one of the most distinguished among young Indian mathematicians associating

himself through his work with the French Mathematical School. Science can make no progress unless by the conjugate efforts of all the nations, for science is essentially international. This latter national character shows itself by the liasion which exists in the work of mathematicians of different countries and by their reciprocal influences on each other. Thanks to you, one of these precious contacts finds itself established between your country and ours. We cordially wish that the relations which have begun in this way, will develop to the common advantage of both our countries and of science."

B. N. Prasad thus became the first Indian to receive the State D. Sc. degree in Mathematics from the Univesity of Paris, a creditable achievement indeed ! His teacher Professor Denjoy was so impressed by Prasad's work that in 1961 in his message of good wishes at the time of Prasad's retirement from active service of Allahabad University, he wrote : (*translation*) :

"About 35 years ago, Professor B. N. Prasad came to Paris to complete the work of his thesis for the degree of Doctor of Science of State-France. He was kind enough to associate myself with the progress of his research work. I could admire week to week, if not day to day, the command with which he handled the more subtle and the more delicate instruments of mathematical analysis for putting in evidence of the propriety of the trigonometric series, independent or conjugate. I remember that in examining his demonstrations, his transformations of the calculus, I imagined a watchmaker, who has to select tools more and more fine, more and more precise, for separating minute wheels.

Returning to India soon after defending his thesis—and in a very brilliant manner —Mr B. N. Prasad had to render in his country eminent services to Indian Mathematics."

Taking advantage of his stay abroad, B. N. Prasad visited centres of mathematical research in England, Scotland, Ireland, France, Germany and Italy and came in personal contact with celebrated mathematicians like Hadamard, Hilbert, Whittaker, Hardy, Lebesgue and others. He returned to India in July 1932 and resumed his duties as Lecturer at the Allahabad University.

Professional Career

Although Dr Prasad returned to Allahabad with conspicuous academic achievements, he failed to get recognition from his employers, the Allahabad University. For full 14 years (upto 1946) he remained a Lecturer, and for another 14 years (till August 1960) he remained a Reader and was appointed Professor only towards the end of his career. It was sheer irony that a person whom any university in India would have been proud to have as its Mathematics Professor 20 years earlier, he chose to serve the Allahabad University as a Lecturer and Reader practically for the entire period of his most productive career.

But these difficulties in the university, could hardly subdue the spirits of Dr Prasad. His keen desire to create an active research centre in Analysis at Allahabad remained throughout uppermost in his mind. He encouraged and inspired bright young students to pursue higher studies and take to a career of teaching and research. Those were the days when there were few scholarships. Salary scales in the

universities were low and employment opportunities were few and above all, the brighter students preferred the administrative services. Undaunted by these handicaps, Dr Prasad succeeded, during 1932–40, in training a band of devoted research workers. Through his indomitable courage and determination, he kept the torch of mathematical research burning at Allahabad. It is gratifying that ultimately his efforts bore fruit; during the forties and fifties, a good number of bright young researchers gathered round him making Allahabad a leading centre of research in Analysis. He succeeded in building at the Allahabad University an active School of Research on Summability Theory, which developed and flourished during his life time and which is appropriately associated with his name. Four of his research pupils were awarded the D. Sc. degree and over a dozen the D. Phil. degree by the Allahabad University, and these have kept research in Summability Theory alive both at Allahabad and at other centres in India. Under his supervision over 150 research papers were prepared and published in various national and international mathematical research journals of repute. When the Government of India instituted National Research Fellowships in 1956, two of them in Mathematics were awarded to Prasad's pupils on the basis of their research work. These were in addition to many others awarded in subsequent years.

Dr B. N. Prasad's teaching career spread over nearly 40 years, out of which $34\frac{1}{2}$ years were spent at Allahabad which he did not choose to leave, although many a time he received offers for higher posts from several universities in India. However, once, in March 1949, he yielded to pressure and accepted an invitation from the Government of Bihar to join the Science College, Patna, as Professor and Head of the Department. But realizing soon that the atmosphere there was not congenial to his academic pursuits, he resigned his professorship and came back to Allahabad in January 1951 to his old post.

Dr Prasad was primarily interested in research, but he was loved and admired by his under-graduate and post-graduate students, for he was an excellent teacher and a source of inspiration to generations of young students. He was a real *guru* in the traditional Indian sense. He helped scores of young men and women (including the author of this memoir) to chalk out suitable and dignified careers for themselves. But he always remained a hard taskmaster and that was perhaps the secret of his success as a research guide.

With the object of creating among students an interest in Mathematics and encouraging original work in the subject, on August 28, 1924, B. N. Prasad founded in the Allahabad University a Mathematical Association with Professor A. C. Banerji, the then Head of the Mathematics Department as President and himself as Secretary. The Association published an Annual Bulletin containing articles written by students and teachers of the Mathematics Department.

During his brief period as Head of the Department (November 1, 1958–January 11, 1961), several noteworthy events took place in the Mathematics Department. For the first time, in December 1958, a Mathematics Exhibition was organized at the Allahabad University which drew praise from distinguished visitors like Sri Jawaharlal Nehru, Sir K. S. Krishnan, Dr H. J. Bhabha and others. Again for the first time during its 50-year existence, in 1959, the Indian Mathematical Society was invited by Dr Prasad to hold its 25th Conference at the Allahabad University.

On the basis of Building Grants sanctioned by the University Grants Commission, through his efforts, Dr Prasad got the Foundation-Stone of the much-needed Mathematics Department Extension Building laid on March 8, 1960. During his regime two important special papers on Numerical Analysis and Linear Operators were introduced for the students of the M. A./M. Sc. (Final) classes. Again, it was through his efforts that the Library of the Department was strengthened by the acquisition of books and journals. When Dr Prasad retired from the Allahabad University on January 11, 1961, a Special Commemorative Issue of the Bulletin of the Mathematical Association was brought out and a memorable and touching farewell given to him by his pupils and friends.

Contributions to Mathematics

The name B. N. Prasad has come to be associated with an extensive cross-section of Modern Analysis including diverse subjects like the Theory of Fourier Series, its conjugate series, their derived series, the theory and applications of absolute summability of infinite series in general, summability factors, Fourier integrals, the concept of radial variation, non-summability in the sense of Abel, the theory of generalized derivatives, strong summability—especially with Riesz' typical means, the Gibbs phenomenon and the generalized jump of a function, the multiplication of Dirichlet series and the second theorem of consistency.

The many D. Sc. and D. Phil. theses submitted from time to time under his supervision and the research papers published round the world in the wake of his own pioneering contributions on these subjects, bear ample testimony to the intrinsic mathematical significance and power of his outstanding work.

In order to give a brief resumè of the important researches of Dr Prasad, it will be convenient to introduce at the outset certain definitions and notations.

Let $f(x)$ be a periodic function, with period 2π, integrable in the sense of Lebesgue over $(-\pi, \pi)$, and let its Fourier series be taken (without any loss of generality) to be given by

$$f(x) = \tfrac{1}{2}a_0 + \sum_{n=1}^{\infty}(a_n \cos nx + b_n \sin nx) \equiv \sum_{n=1}^{\infty} A_n(x). \qquad ..(1)$$

Then the series

$$\sum_{n=1}^{\infty}(b_n \cos nx - a_n \sin nx) \equiv \sum_{n=1}^{\infty} B_n(x), \qquad ..(2)$$

is called the conjugate series of the Fourier series of $f(x)$. We shall also write

$$\left.\begin{aligned} \phi(t) &= \tfrac{1}{2}[f(x+t) + f(x-t) - 2f(x)], \\ \psi(t) &= f(x+t) - f(x-t) \\ \Phi(t) &= \int_0^t \phi(u)du. \end{aligned}\right\} \qquad ..(3)$$

Denoting by S_n^{α} the nth Cesáro mean of order α of the sequence of partial sums $\{s_n\}$ of any given infinite series Σu_n, we say that Σu_n is summable (C, α) to the sum S, if $\lim_{n \to \infty} S_n^{\alpha} = S$, and summable $| C, \alpha |$ if $\Sigma | S_n - S_{n-1} | < \infty$. If $\Sigma u_n x^n$ is convergent for $| x | < 1$ and equal to $f(x)$, then Σu_n is said to be summable (A) to S, if $\lim_{x \to 1-0} f(x) = S$, and summable $| A |$ if $f(x) \in BV(0, 1)$. If we write

$$R_\lambda^k(\omega) = \omega^{-k} \sum_{\lambda_n < \omega} (\omega - \lambda_n)^k \, u_n, \; k \geqslant 0,$$

then Σu_n is said to be summable (R, λ_n, k) to S, if

$$\lim_{\omega \to \infty} R_\lambda^k(\omega) = S,$$

and summable $| R, \lambda_n, k |$ if $R_\lambda^k(\omega) \in BV(A, \infty)$, for some finite $A > 0$.

Convergence and Summability of Fourier Series

A generalization of the classical result of Fejér, the well-known result of Lebesgue that the Fourier series of a periodic function which is integrable (L) is summable $(C, 1)$ almost everywhere, was indeed one of the turning points in the theory of summability of Fourier series. Hardy proved in 1913 that the order of summability could be reduced to $\delta > 0$. The set of points considered by Lebesgue was the set of points x, at which $\int_0^t | \phi(u) | du = o(t)$, as $t \to \infty$, the so-called 'Lebesgue set' which certainly is more general than the set of points at which $\phi(t) = o(1)$, as $t \to 0$. Indeed, Lebesgue's criterion may be valid even at the points of discontinuity of the second kind. The fundamental result of Lebesgue was generalized in another direction by Noaillon and Young and ultimately by Hardy by replacing the condition that x belongs to the Lebesgue set by the couple of conditions

(*i*) $(1/t) \int_0^t \phi(u) \, du$ exists as $t \to 0$, and

(*ii*) $\int_0^t | \phi(u) | \, du = O(t)$,

which may be satisfied even at points outside the Lebesgue set, but which are of course satisfied at points of the Lebesgue set. Cases were, however, known in which the Fourier series was summable $(C, 1)$ even when the limit of $\Phi(t)/t$, as $t \to 0$, does not exist. One of the problems that Prasad successfully tackled (1934) was the question of the Cesàro summability of the Fourier series of $f(t)$, at a point $t = x$, where this limit fails to exist. The basic technique developed by Prasad for the solution of this problem in the case of $(C, 1)$ summability is to reduce the discussion of the $(C, 1)$ summability of $f(t)$, at $t = x$, that is, of $\phi(t)$, at $t = 0$, to the convergence of the Fourier series of $\Phi(t)/t$, i.e., $\phi_1(t)$, at the same point. In thus reducing the problem of summability to an associated problem of convergence, Prasad had automatically been led to a number of criteria of summability $(C, 1)$ depending upon the already known criteria for convergence of a Fourier series at a point. He proved, *inter alia,* that the existence of the integral $\int_0^\delta \Phi(t) \, t^{-2} \, dt$ is sufficient for the summability $(C, 1)$ of the Fourier series of $f(t)$, at $t = x$. This criterion may be applicable even when the limit of $\Phi(t)/t$ does not exist, as is demonstrated by the following example :

$$\Phi(t) = n^{-2} \sin^2 \{n^4 (t - n^{-2})\pi\} \; (n^{-2} \leqslant t \leqslant n^{-2} + n^{-4}),$$

and $\Phi(t) = 0$, elsewhere.

It is known that the following three conditions are in descending order in respect of their degrees of stringency, so that each will hold if the preceding one holds, but not vice versa :

$\int^\delta | \phi(t)/t | \, dt$ exists, ...(4)

$\int_0^\delta \{\Phi(t)/t\} \, dt$ exists as a non-absolutely convergent integral ...(5)

and $$\Phi(t) = o\,(t), \text{ as } t \to 0. \qquad \ldots(6)$$

It is also known that when (4) holds, the Fourier series is convergent by Dini's condition and hence also summable $(C, 1)$. When (5) is satisfied, it is known that the Fourier series is not necessarily convergent. Hahn had investigated if, at a point x, the holding of the condition (6) is a sufficient condition for the summability $(C, 1)$ of the Fourier series of $f(t)$, at $t = x$, and he had construed an example to prove that the answer was in the negative. The more delicate investigations as to the summability or non-summability of Fourier series, when the more stringent condition (5) is satisfied, were taken up by Prasad, who showed (in 1935) by constructing an example that even when the condition (5) is satisfied, the Fourier series, although summable $(C, 1 + \delta)$ for every $\delta > 0$, is not necessarily summable $(C, 1)$.

Convergence and Summability of the Conjugate Series of a Fourier Series

Prasad's contributions to the theory of convergence and summability (C) and (A) of the conjugate scries have had far-reaching influence on later developments. It is well known that a conjugate series is not necessarily a Fourier series. It had been customary to associate with the conjugate series the conjugate function $g(x)$ given by

$$\left.\begin{aligned} g(x) &= (1/2\pi) \int_0^{\pi} \{f(x+t) - f(x-t)\} \cot \tfrac{1}{2}t \; dt \\ &= (1/2\pi) \int_0^{\pi} \psi(t) \cot \tfrac{1}{2}t \; dt \\ &= (1/\pi) \int_0^{\infty} \psi(t) / t \; dt, \end{aligned}\right\} \qquad \ldots(7)$$

on account of the periodicity of $f(t)$, and to look upon this almost *a priori* as the sum function and then discuss the convergence and summability of the conjugate series, at the point $t = x$, to $g(x)$ under suitable additional restrictions imposed upon $\psi(t)$. Prasad not only gave general criteria (1931) for the convergence of the conjugate series, at a point, but also made (1931–32) a rather comprehensive study of its $(C, 1)$ summability. By means of a technique, parallel to the one he had used for the Fourier series, he deduced a number of $(C, 1)$-summability criteria, some of which may be mentioned as follows.

If the integral $g(x)$ exists at least as a non-absolutely convergent integral, then the conjugate series is summable $(C, 1)$ to $g(x)$ provided

$$\text{the integral } \int_0^{\delta} |\, \psi(t) \,|\, t^2 \, dt \text{ exists} \qquad \ldots(8)$$

or $$(1/t) \int_0^{t} du. \; (1/u) \int_0^{u} \psi(v) \, dv \text{ is of bounded variation} \qquad \ldots(9)$$

or $$\int_0^{t} |\, \psi(t) \,| \, dt = O(t). \qquad \ldots(10)$$

The criterion (10) includes as a particular case Young's criterion for the summability $(C, 1)$ of the conjugate series, at $t = x$, viz., if $g(x)$ exists then the conjugate series is summable $(C, 1)$ to $g(x)$, provided

$$\int_0^t | \psi(t) | dt = o(t).$$

But Prasad raised a crucial question : What can be asserted about the $(C, 1)$ summability at a point x, at which $g(x)$ fails to exist ? Prasad proved that the earlier theorems on $(C, 1)$ summability including those corresponding to the criteria (8), (9) and (10), continue to be true even when $g(x)$ fails to exist, provided, what Prasad terms, the 'generalized conjugate function'

$$G(x) = (1/4\pi) \int_0^\pi \Psi(t) \operatorname{coses}^2 \tfrac{1}{2}t \, dt \qquad \ldots(11)$$

exists. Naturally, this result had a far-reaching effect on the theory of Cesàro summability of the conjugate series.

It was known that the integral $g(x)$ exists for almost all values of x and also that the summability (C, δ), for $\delta > 0$, of the conjugate series for almost every x, more precisely for every x where

$$\int_0^t | \psi(u) | du = o(t),$$

as $t \to 0$, is equivalent to the existence of the function $g(x)$ so that it finally emerges that the conjugate series is summable (C, δ) almost everywhere. This too is readily deducible from the well-known theorem of Hardy and Littlewood that in the Lebesgue set the conjugate series is either summable by every Cesàro mean of positive order or summable by no Cesàro mean in conjunction with the fact that the conjugate series is summable $(C, 1)$ at every point of the Lebesgue set. Thus for almost all points a necessary and sufficient condition for the summability (C, δ), $\delta > 0$, of the conjugate series is the existence of $g(x)$. Prasad had shown that if $f(t)$ is bounded then the conjugate series is summable (C, δ), for every $\delta > 0$, to $g(x)$, whenever $g(x)$ exists. Also Hardy and Littlewood showed that for such an $f(t)$ the existence of $g(x)$ is a necessary condition for summability (C, δ), for $\delta > 0$, of the conjugate series at $t = x$.

The question naturally arose whether the existence of $g(x)$ *by itself* is sufficient to ensure the summability (C, δ), $\delta > 0$, of the conjugate series at $t = x$. Prasad proved (1932) that this is not so in general, even for $\delta = 1$, by constructing a negative example. The construction of such an example, however, essentially depends upon a suitable type of another example, for which, at a point, the original function is continuous and also the integral $g(x)$ exists, but still the corresponding conjugate series fails to converge at that point. In case the conjugate function $g(x)$ does not exist, but the generalized conjugate function $G(x)$ exists, Prasad has proved that the conjugate series will still be summable (C, δ), for $\delta > 1$, provided

$$\Psi(t) = o(t), \text{ or even } \int_0^t | \Psi(t) / t | dt = o(t).$$

Summability (C,r), r > 0, of the Conjugate Series

Prasad developed a merit by which sufficient conditions for summability (C, r), $r > 0$, of the conjugate series as also the sum to which it is summable could be obtained in a simple manner. He proved that if

$$\chi_r(t) = \int_0^t (dt_1/\sin t_1) \int_0^t (dt_2/\sin t_2) \ldots \int_0^{t_{r-2}} (dt_{r-1}/\sin t_{r-1}) \int_0^{t_{r-1}} \Psi(t_r)\, dt_r'$$

$$\chi_1(t) = \int_0^t \psi(u)\, du = \omega_1(t),$$

$$\omega_r(t) = \int_0^t (dt_1/t_1) \int_0^{t_1} (dt_2/t_2) \ldots \int_0^{t_{r-2}} (dt_{r-1}/t_{-1c}) \int_0^{t_{r-1}} \dot{\psi}(t_r)\, dt_r'$$

and if the $(r + 1)$ the generalized integral

$$G_{r+1}(x) = (1/4\pi) \int_0^\pi \chi_{r+1}(t) \operatorname{cosec}^2 \tfrac{1}{2}t\, dt$$

exists, then the conjugate series is summable (C, r) to $G_{r+1}(x)$, provided that

$$\lim_{n\to\infty} \int_0^\delta [(\omega_r(t))/t] (\cos nt)/t\, dt = 0,\ 0 < \delta < \pi.$$

From this he obtained tests for the summability (C, r) of the conjugate series, corresponding to those for the summability $(C, 1)$.

The results of Prasad have since been extended by some of his students and also by other mathematicians but the merits of his work lies in the introduction of the generalization $G(x)$ of the conjugate function $g(x)$. This idea of Prasad opened new avenues for further research. His methods are simple and elegant, his tools mostly classical, but he used them with great skill to arrive at important results of profound significance.

Abel Summability of the Conjugate Series

A method of summability which is more delicate than the Cesàro summability of any positive order is that due to Poisson—now more familiar as the Abel summability method. Applying this method to the study of the conjugate series at a point, Fatou had proved (1906) that if

$$V(r, x) = \sum_{n=1}^{\infty} (b_n \cos nx - a_n \sin nx)\, r^n,\ 0 \leqslant r < 1,\ \epsilon = \sin^{-1}(1-r),$$

then

$$\lim_{r\to 1} \quad [V(r,x) - (1/2\pi) \int_\epsilon^\pi \psi(t) \cot \tfrac{1}{2}t\, dt] = 0,$$

provided that $f(t)$ is a bounded and continuous function. Lichtenstein showed that for the truth of this result it is sufficient that x be a point of continuity of $f(t)$. Later Plessner (1923) and Prasad (1931) demonstrated that the result holds for every point $t = x$, for which $\Psi(t) = o(t)$ as $t \to 0$. Subsequently, Prasad showed

that the result would remain true in a more general sense under a less stringent condition; more precisely, he showed that

$$\lim_{r \to 1} \left[V(r,x) - (1/4\pi) \int_{\epsilon}^{\pi} \Psi(t) \operatorname{cosec}^2 \tfrac{1}{2}t \, dt\right] = 0,$$

provided that

$$\lim_{t \to 0} (1/t) \int_{0}^{t} [\Psi(t)/t] \, dt = 0.$$

Prasad also showed (1932) that if the integral

$$g(x) = (1/2\pi) \int_{0}^{\pi} [f(x+t) - f(x-t)] \cot \tfrac{1}{2} t \, dt$$

diverges to $+\infty$ or $-\infty$, the Abel-limit of the conjugate series at $t = x$ will also diverge to the same value.

Absolute Summability : | A | method

The concept of summability, as a generalization of convergence, had become well known even before the beginning of the 20th century, but not until 1911 the concept of absolute summability as the corresponding generalization of absolute convergence was developed. While the initial work on absolute Cesàro summability was done by Fekete and Kogbetliantz by 1925, the absolate Riesz summability was brought into existence in 1929 by Obrechkoff. It was a coincidence that when in early thirties Prasad began his work in England on absolute summability, Whittaker defined the method of absolute Abel summability. He also showed that Dini's convergence criterion was also a criterion for the summability | A | of a Fourier series at a point. Taking up t e thread immediately, Prasad brought about a striking improvement in the then existing situation by proving that Jordan's convergence criterion was also a | A | summability criterion for the Fourier series at a point. He also established a number of results with increasing degrees of generality on the absolute Abel summability of the conjugate series at a point. There is, however, one particular contribution by Prasad, which is of a very specific nature. Whittaker had shown it to be possible for a Fourier series to converge at a point without being summable— | A | at that point. The natural question which arose thereafter was whether absolute Abel summability implied convergence at a point. Prasad settled this question in 1930 by demonstrating that a Fourier series may be summable | A | at a point without being convergent there, thus establishing the independence of convergence and summability | A | of Fourier series.

Although Prasad's work on the absolute Abel summability of Fourier series and its conjugate series greatly influenced the work of contemporary mathematicians like Bosanquet, Kuniyeda, M. L. Misra, Takahashi, Hyslop and others, significant contributions made by Bosanquet need a special mention, which emerged from his attempt at generalizing Prasad's result on absolute Abel summability and were concerned with the more stringent absolute Cesàro summability of a

Fourier series and its conjugate series at a point. It will be no exaggeration to state that it were the researches of the three pioneers—Whittaker, Prasad and Bosanquet—which gave the initial impetus for most of the work on the absolute summability of the Lebesgue-Fourier series.

Absolute Summability Factors

One of the most interesting aspects of the recent researches on Fourier series pertains to the determination of suitable factors $\{\lambda_n\}$ such that the series $\Sigma\lambda_n A_n(t)$ may be summable in some prescribed sense. Such factors are known as 'summability factors' of Fourier series. When the summability method in question is absolute, these factors are known as 'absolute summability factors' of Fourier series.

The first applications of absolute summability factors of Fourier series were due to Prasad (1933). He proved the following theorem :

If $\{\lambda_n\}$ be any of the sequences

$$[\log n)^{1+\epsilon}]^{-1}, [\log n\ (\log\log n)^{1+\epsilon}]^{-1}, \ldots, [\log n\ (\log\log n)\ldots .. (\log..\log_p n)^{1+\epsilon}]^{-1},\ \epsilon > 0, \quad ..(12)$$

then $\Sigma\lambda_n A_n(t)$ is summable $|A|$ at every point $t = x$, where

$$\int_0^t |\phi(u)|\, du = o(t), \quad ..(13)$$

as $t \to 0$.

Since the condition (13) holds for almost all values of x, it follows that factors of the type (12) are $|A|$ -summability factors of the Fourier series $\Sigma A_n(t)$ for almost all values of t. This result has its analogues for the conjugate series and restricted Fourier series of second class, which also Prasad established in course of his researches. This result of Prasad formed the basis of a series of results proved in later years by Izumi and Kawata (1938), Cheng (1948), Pati (1954), Pati and Sinha (1958) and others.

Using his results relating to summability $|A|$ of trigonometric series, Prasad investigated conditions under which the sum of a power series, with the unit circle as its circle of convergence, is a function of bounded variation on a radius vector, and proved important results in this regard. The following is one of them :

If a power series $\Sigma c_n z^n$ $(z = r\, e^{i\theta})$ with bounded coefficients is such that its second integrated series, which necessarily converges uniformly on the circle of convergence, has for sum a function of θ, whose second order derivative is a function of bounded variation, for all points of an arc, then the sum of the power series is a function of bounded variation on every radius vector in that arc.

Work done in Collaboration with Pupils

Izumi and Kawata and Cheng extended Prasad's result on $|A|$ -summability factors of Fourier series while Pati obtained generalizations which contained both of these results as special cases. Prasad and Bhatt gave further extensions (1957) and a number of allied results of various kinds in the same direction.

Prasad and Siddiqi extended the scope of summability of the derived Fourier series (1949) by applying Nörlund means instead of Cesàro means, which had been used earlier by Chen and others. Prasad and Siddiqi later obtained a very

general result concerning the Nörlund summability of the r-th derived Fourier series, generalizing earlier results proved by Astrachan, Zygmund and Wang. This result appeared in 1950. In 1958 they obtained very detailed results on the determination of the *jump of a function* by means of the Nörlund means of its Fourier series and on the *Gibbs phenomenon* studied in similar context.

Prasad and U. N. Singh worked on the strong summability of order unity of the derived series of a Fourier series at a point, the generating function being assumed to be of bounded variation in the fundamental interval. This result was a source of inspiration for some of the subsequent researches on the subject.

To Obrechkoff is due the first theorem of consistency for absolute Riesz summability which asserts that if a series is summable $| R, \lambda, \alpha |$, $\alpha \geqslant 0$, then it is also summable $| R, \lambda, \beta |$ for every $\beta > \alpha$. The consequence of this theorem is that if the type remains unchanged, the effectiveness of the absolute Riesz summability method increases with the order. Since summability $| R, \lambda, 0 |$ is equivalent to absolute convergence, it is obvious that the Riesz summability method is an absolutely regular one.

The inclusion relation of the kind $| R, \lambda_n, k | \subset | R, \phi(\lambda_n), k |$, where the types are different but the orders are identical, constitute what is called the 'second theorem of consistency' for the absolute Riesz summability. The general result in this direction is that if the order of summability remains the same, then for the absolute summability, the efficiency of the Riesz means increases, or at any rate does not decrease, as the rate of increase of the type decreases. The first theorem in this direction was obtained by Chandrasekharan (1942) as analogue for absolute summability of Hardy's well-known extension of the classical 'Second Theorem of Consistency' for ordinary Riesz summability. This theorem was generalized (1954) by Pati for integral orders. An improvement on Pati's result was effected by Guha (1956), who also established a result for the case of non-integral order of summability. For non-integral orders, Prasad (1958) and Prasad and Pati (1957, 1960) obtained results in which great simplicity has been affected on the conditions required. They have proved :

If $\phi(t)$ is a non-negative, monotonic increasing function of t, for $t \geqslant 0$, steadily tending to infinity as $t \to \infty$, such that $\phi(t)$ is a $(\kappa + 1)$th indefinite integral, for $t \geqslant 0$, κ being the integral part of k (assumed non-integral),

$$t^{k+1}\, \phi^{(k+1)}(t) / \phi(t) \in B(h, \infty),$$

where h is a finite positive number, and, uniformly in $0 < v < 1$ and $s > 0$,

$$\Lambda = s^{\kappa} \left\{ \frac{(1-v)\, t}{\phi(s+t) - \phi(s+vt)} \right\}^{k+1-\kappa} \left[\frac{\{\phi^{(1)}(s+vt)\}^{k+1}}{\{\phi(s+t)\}^{\kappa}} \right] \in BV_t\,(h, \infty),$$

then any infinite series which is summable $| R, \lambda_n, \kappa |$ is also summable $| R, \phi(\lambda_n), \kappa |$. In particular, the result of the above theorem remains true if Λ is replaced by $\phi^{(1)}(t)$, monotonic and non-decreasing.

Denoting by (*) the hypothesis of these theorems, we may observe that by virtue of the first theorem of consistency, $| R, \lambda_n, k | \subset | R, \phi(\lambda_n), k^1 |$, $k^1 > k$, under (*). Prasad (1954) suggested the possibility of establishing the above theorem by taking less stringent conditions than those in (*). More generally, he suggested the investigation of problems what he termed 'the unified theorems of consistency'

which assert $| R, \lambda_n, k | \subset | R, \mu_n, k' |$, that is, when the type as well as the order both vary.

The formal product of two Dirichlet series $\Sigma a_n e^{-\lambda_n s}$ and $\Sigma b_n e^{-\mu_n s}$, arranged according to the ascending order of the sums $\nu_n = \lambda_p + \mu_q$, determines the series $\Sigma c_n e^{-\nu_n s}$, where $c_n = \sum_{\nu_n = \lambda_p + \mu_q} a_p b_q$ and Σc_n defines the "Dirichlet Product" of the series Σa_n and Σb_n of type (λ, μ). Among many theorems for the various kinds of summability of the Dirichlet product Σc_n, with reference to summability conditions on Σa_n and Σb_n, we have the following :

If Σa_n is summable $| R, \lambda, k |$ and Σb_n is summable $| R, \mu, l |$, then Σc_n is summable $| R, \nu, k + l |$ [Obrechkoff, 1929].

This theorem gives, in particular, that if $\Sigma a_n e^{-\lambda_n s}$ is summable $| R, \lambda, k |$ for $s = s_1$, and $\Sigma b_n e^{-\mu_n s}$ is absolutely convergent for $s = s_2$, where $\sigma_2 > \sigma_1 \geqslant 0$, then $\Sigma c_n e^{-\mu_n s}$ is summable $| R, \nu, k |$ for $\sigma = \sigma_2$. In the case when k is an integer, a direct proof of this result was given by Pati (1960). Again a combination of the theorem given above and a limitation theorem due to Isaacs (1953) gives us that if $\Sigma a_n e^{-\lambda_n s_1}$ is summable $| R, \lambda, k |$ and $\Sigma b_n e^{-\mu_n s_2}$ is summable $| R, \mu, l |$, $\sigma_2 \geqslant \sigma_1 > 0$, then

$$e^{-sx} x^{-(k+l)} C\nu^{k+l}(x) \in BV(c, \infty), \sigma > \sigma_2 \geqslant \sigma_1 0.$$

In 1960, Prasad and Pati proved that if k and l be integers, then the above result holds also for $\sigma = \sigma_2 = \sigma_1 > 0$.

The theory of strong summability of a Dirichlet series is of recent origin and has been worked out mainly by Richert (1955, 1956, 1960), P. Srivastava (1956, 1960) and Prasad and P. Srivastava (1960). This theory in some sense, provides for a unified treatment of both ordinary summability and absolute summability of a Dirichlet series; and in the case of an ordinary Dirichlet series it has been shown to have a more direct relationship with the function-theoretic behaviour of the sum-function and has applications in the asymptotic number theory as well.

If the series $\Sigma a_n e^{-\lambda_n s}$ is summable $[R, \lambda, k, q]$ at a point s^*, then it is summable $(k-1) | R, \lambda, k, q |$ for every value of s, such that $\sigma > \sigma^*$. Moreover if, for $q \geqslant 1$, $q + 1 > 0$, $\sigma^* > 0$, the above Dirichlet series is summable or bounded $[R, \lambda, k, q]$, then, as $\omega \to \infty$,

$$A_\lambda^{k,q}[\omega] = \int | A_\lambda^{k-1}(x) |^q dx = \begin{cases} o(e^{q\sigma^*} \omega^{(k-1)q+1}) & (\text{or } O(\ldots)), \\ \text{or} \\ o(e^{q\sigma^*} \omega^{kq}) & (\text{or } O(\ldots)), \end{cases}$$

according as k is or is not an integer; and conversely, if for $q \geqslant 1$, $k > 0$,

$$A_\lambda^{k,q}[\omega] = o(e^{q\sigma\omega}), \quad \omega \to \infty,$$

for every $\sigma > \sigma^*$, then the given Dirichlet series is summable $[R, \lambda, k, q]$ for $\sigma > \sigma^*$. This result was established by Prasad and Srivastava in 1960 and has many important consequences as mentioned below.

From the above theorem we deduce that there exists an abscissa of summability $[R, \lambda, k, q]$, such that, as usual, the Dirichlet series is strongly summable at every point to the right of the line given by this abscissa and is not summable $[R, \lambda, k, q]$

at any point to the left of this line. With the help of the theorem, values of the abscissae of summabilities $[R, \lambda, k, q]$ and $[R, l, k, q]$ have been calculated and it has been shown that the abscissae of these two summabilities are equivalent. It has also been shown that if $q = 1$, $\gamma_{k,q} = g_k$ and if $q = \infty$, $\gamma_{k,q} = \sigma_k$ where $\gamma_{k,q}$ denotes the abscissa of the summability. Considered as a function of k, this abscissa is convex and considered as a function of $1/q$ also it is convex.

Prasad and D. P. Gupta in 1965 studied the convergence of ultraspherical lacunary series. They proved the following theorem :

If $\{n_i\}$, $i = 1, 2,..$ be a sequence of positive numbers satisfying the condition $n_{i+1}/n_i \geqslant q > 1$, and the Fourier ultraspherical coefficients a_n for $f(x) \in L^2(-1,1)$ in

$$f(x) \sim \sum_{n=1}^{\infty} a_n p_n^d(x) \text{ where}$$

$$a_n = \frac{(n+\lambda)\Gamma\lambda\Gamma(n+1)\ \Gamma(2\lambda)}{\Gamma(\frac{1}{2}+\lambda)\ \Gamma(\frac{1}{2})\ \Gamma(n+2\lambda)} \int_{-1}^{1} f(x)\ (1-x^2)^{1-\frac{1}{2}}\ P_n^{(\lambda)}(x)\ dx$$

and $P_n^{\omega}(x)$ is the ultraspherical polynomial of order λ given by the generating function

$$(1-2xz+z^2)^{-\lambda} = \sum_{\approx n=0}^{\infty} z^n\ P_n^{(\lambda)}(x).$$

be all zero except for $n = n_i$ then the series $\Sigma a_i\ P_{ni}^{(\lambda)}(x)$ converges to $f(x)$ almost everywhere in $(-1, 1)$ and the series $\sum_{i=1}^{\infty} (a_i^2/n_i^{2\lambda})$ converges for $1 > \lambda \geqslant 1/2$.

All these papers were written in forties, fifties and sixties and one can discern the stamp of the master on their style.

Among a very large number of references to Prasad's work in mathematical literature mention may be made of those by Hardy and Littlewood (1931), Bosanquet (1933, 1934), Takahashi, Izumi and Kuniyeda (1934), Moursund (1936), Bosanquet and Hyslop (1937), Smith (1938), Hsiang (1946), Cheng and Anderson (1947), Rudin (1955), Zygmund (1935 : in his treatise on '*Trigonometric Series*'), Titchmarsh (1938 : in his treatise on '*Introduction to the Theory of Fourier Transforms*') and the '*Progress of Science in India during the Past 25 years*' (1938 : Indian Science Congress : Silver Jubilee Volume).

Association with Scientific Bodies

Indian National Science Academy (formerly National Institute of Sciences of India)

He was among the earlier elected Fellows of this premier scientific body of the country. He served on its Council, Editorial Board and various committees, and was its Vice-President in 1961–62.

Indian Science Congress Association

One of the Life Members of the Association, he had the honour of being elected as President of the Section of Mathematics & Statistics (1944–45), General Secretary (Outstation) (1952–55 and 1958–61) and its General President (1965–66).

He was the first mathematician to be elected General President of the Indian Science Congress during its 53 years of existence.

National Academy of Sciences of India

He was elected a Fellow of the Academy even when the number of its Fellows was limited to 30. He had been President of the Physical Sciences Section (1960) its Vice-President and later its President (1965–66).

Indian Mathematical Society

One of the Life Members of the Society, he had the honour of serving on the Council of the Society for many years and of being its President in 1961. During his tenure of office as President, he strengthened its organizational and academic structure.

Calcutta Mathematical Society, Bharat Ganita Parishad & Vijñan Parishad

He was a Vice-President of the Calcutta Mathematical Society and *Vijñan Parishad* and a Member of the Managing Committee of the *Bharat Ganita Parishad.*

Foreign Societies

He was a Member of the London Mathematical Society and *Societè Mathematique de France*, and was a Reviewer for *Mathematical Reviews* of the American Mathematical Society.

Long-Cherished Dreams Fulfilled

While in the United Kingdom, on January 1, 1930, B. N. Prasad wrote in his diary about the necessity and desirability of starting an all-India Mathematical Society and of publishing a first-rate mathematical research journal under its auspices. He also wrote about the necessity of starting an Institute of Mathematics in India for the advancement of quality research in the country. Even to him, at that time, these ideas were no more than a dream and it is given to few people in the world that their dreams get fulfilled within their life time. Prasad was one of those fortunate few.

He believed that a Mathematical Society should not only organize annual conferences and publish research journals, but also devise and successfully execute constructive programmes for promoting quality research in the country. With this goal, at his initiative, the Allahabad Mathematical Society was founded in November 1958, with 20 Founder Members and with Dr B. N. Prasad as its first President. The Society decided to publish its new research journal, the Indian Journal of Mathematics. During the past 25 years (1958–83) the Society and its Journal have stood the tests of time and have earned for themselves an international status and recognition, thus fulfilling his first dream.

As to his second one, in the year 1964, at the initiative of this author, negotiations started between Professor Prasad and Sri Girdharilal Mehta, Chairman of the B. S. Mehta Trust, Calcutta, to set up a Research Institute of Mathematics and Mathematical Physics at Bharwari (Dist. Allahabad)—about 40 kilometers from the city of Allahabad. Professor Prasad had the satisfaction that this new Research Institute, as envisaged by him, will start functioning soon, which it actually did from 19 July 1975, under the sponsorship of the Government of India (through the Department of Atomic Energy), the State Government of Uttar Pradesh, the B. S. Mehta Trust of Calcutta and the B. N. Prasad Memorial Trust at Allahabad (set up by the Allahabad Mathematical Society).

His Presidential and Other Addresses

1945 : To the Mathematics & Statistics Section of the Indian Science Congress at Nagpur, he delivered his Presidential Address entitled *The Summability of Fourier series and its conjugate series*, in which he presented an excellent survey of the work done, upto 1944 concerning the summability problems (of various kinds) of a Fourier series and its conjugate series, with a bibliography of 175 research papers at the end.

1954 : To the Bundelkhand College (Agra University) at Jhansi, he delivered a Convocation Address telling the new graduates that "*Every organic institution has either to grow up and live or perish. This is all the more true of Centres of Learning. Unless the mind and spirit are progressively brought to higher and yet higher planes of fulfilment, the very purpose of education will be defeated.....How welcome should be any movement that aims at developing a healthy environment around the universities and colleges through social services and academic and cultural activities of the students.*"

1960 : To the Physical Sciences Section of the National Academy of Sciences of India at Gorakhpur, he delivered his address on "*The Absolute Summability of Fourier Series*" presenting an up-to-date account of the research work done in this rather recent branch of Summability Theory, his own students having contributed a good deal to it. He himself had a pioneering role in developing this branch.

1961 : To the Indian Mathematical Society at Ahmedabad, he delivered a General Address on *Mathematics in India* and a Technical Address on "*Certain aspects of the Researches on Dirichlet Series.*" In the first part he put forward his own ideas and suggestions for improvement of Mathematical Teaching and Research in the country. He pleaded for better service conditions for teachers in colleges and universities, for making our syllabuses up-to-date without making the changes too abrupt and radical, for establishment of centres of research in different parts of the country and for the university authorities cooperating with these centres of research in every possible manner. In the technical part, he presented an account of the work done on the summability of Dirichlet series—ordinary, absolute and strong : Riesz and Abel summability, as also the summability of Dirichlet product of summable series.

1963 : To the *Vijnan Parishad* at Delhi he delivered a Presidential Address at a symposium on "Hindi Medium, Mathematical studies and Research (हिन्दी माध्यम, गणितीय अध्ययन और अनुसंधान)," in which he put forward his own ideas about publishing mathematical research papers in Hindi. While on one hand he was of the view that education at the primary and secondary levels must be through regional languages a research journal exclusively in Hindi should not be published till we have seen that Hindi is accepted as an international language.

1966 : To the 53rd session of the Indian Science Congress at Chandigarh, he delivered a General Presidential Address. The first part of the address was entitled "*Science in India*" and the second, technical part, was on "*Recent Researches in the Absolute Summability of Infinite Series and their Applications.*" In the first part, he suggested a number of steps to be taken at the national level to attract brilliant young men and women to a scientific research career, to be followed while selecting teachers in colleges and universities and while giving them promotions, to be kept in view while permitting young students to go abroad for studies in subjects in which facilities for research exist in India, and for setting up high rank Research Institutes in different parts of the country so that due attention be paid to all aspects of research : pure, applied and development.

In the technical part, which contained a bibliography of over 300 published papers, he presented a detailed and up-to-date account of researches done all over the world in the field of absolute summability of infinite series, with special reference to Fourier series and Dirichlet series. This was the subject to which Professor Prasad devoted his entire professional career.

1967 : To the Allahabad Mathematical Society on the occasion of its First Conference at Allahabad a (posthumous) Presidential Address on *Development of Science in India after Independence,* in which he discussed in reasonable detail the developments that had taken place during the first 20 years after gaining independence, in various branches of Science—Physical, Biological, Agricultural etc.

Recognition by the Government of India

Dr Prasad's efforts towards the advancement of mathematical researches and scientific and mathematical education in the country were repeatedly recognized not only by the learned scientific bodies of India and abroad, but also by the Government of India from time to time. To enumerate some :

1951 : In the first International Conference of the Pan-Indian-Ocean Science Congress Association held at Bangalore he was appointed to represent India for the subject of Mathematics.

1954 : He was sent as the Scientist Member of Government of India's Five-Member Delegation, under the leadership of the then Vice-President, Dr S. Radhakrishnan, to represent India in the Eighth UNESCO General Conference held at Montevideo (South America). In this trip he also visited a number of universities in the U.S.A. and gave research lectures.

1958 : He was sent by the Government of India to represent the Indian Science Congress Association at the 120th Conference of the British Association for Advancement of Science, held at Glasgow. He was also a delegate to represent India at the International Congress of Mathematicians held at Edinburgh and was also invited to deliver lectures at the Cairo University in Egypt.

1959 : Appointed by the University Grants Commission, New Delhi, as Member of its Review Committee for Mathematics and Statistics to "*broadly survey and assess the standard of teaching and research and the facilities available for the purpose and to recommend steps to be taken in order to raise the general level of academic attainment and research in Indian universities.*"

1960 : Appointed by the Government of India to be a Member of the Committee set up to explore the possibilities of adding some new departments, including that of Mathematics, to the newly-established University of Jabalpur (M.P.). Also appointed a Member of the Governing Council of the Indian Statistical Institute, Calcutta.

1963 : In recognition of his meritorious services to the cause of Science and Education in India, the President of India conferred upon him the title of *Padma Bhushan*, the first Indian mathematician to be so honoured.

1964 : A year later, he was once again honoured by the President of India by being nominated to be a Member of Parliament (Rajya Sabha). During the only two years he had at his disposal, he made significant contributions to the deliberations of the Rajya Sabha.

1965 : As its General President, he was appointed to represent Indian Science Congress Association once again at the Conference of the British Association for Advancement of Science.

Association with Indian Universities

He was member of the Court, Executive Council, Academic Council, Faculties of Arts, Science and Commerce and Committee of Courses and Board of Studies in Mathematics of the Allahabad University; of the Executive Council, Court, Senate, Faculties of Arts and Science and Board of Studies in Mathematics of Banaras Hindu University; of the Board of Studies in Mathematics of Agra, Saugor and Baroda universities; and of various such academic bodies of the Patna and Bihar universities. He was also connected with a number of other Indian universities.

Family Life and Social Virtues

On May 29, 1923, B. N. Prasad was married to Lakshmi Devi, a very accomplished, kind-hearted and cultured lady. They had three children : one son, Prakash Chandra and two daughters, Indu Prabha and Arun Prabha (died 1979), all of whom got well-settled in life. The family lived happily together till the death of Mrs Prasad on September 15, 1954, at Patna after a prolonged illness. This left a big gap in the otherwise happy life of Dr Prasad, who, in order to keep away from feelings of sadness, kept himself extremely busy all the day round.

A strict disciplinarian, Prasad was an ardent devotee of truth and honesty. His straight and upright behaviour, his mathematically precise and exact way of approach towards every problem, his keen desire to see his department flourish in every manner, coupled with his efforts towards achieving this end, and, above all, the nobility of his character, could not but deeply influence any one who desired and had the opportunity to come in close contact with him. A man of highly refined aesthetic taste, polished manners and dynamic and impressive personality, Dr Prasad carried the weight of his learning very lightly. A voracious reader, he hardly allowed to escape any opportunity to learn something new.

Prasad was greatly hospitable at home. He enjoyed entertaining his friends and pupils, particularly when an Indian or foreign scientist or educationist visited Allahabad and stayed with him. The author recalls with pleasure having met some eminent men from all over the world, including Norbert Wiener, Marshall H. Stone, Linus Pauling, P. A. M. Dirac, Mahapandit Rahul Sankrityayan, S. N Bose, Acharya Narendra Dev, and many others.

B. N. Prasad's was a dedicated life. He passed through many ups and downs. At times he faced the severest of crises, but he kept his banner high in the bivouac of life. It is no exaggeration to say that, to all seekers of truth in Mathematics, he *will live forever among those who have raised the spirit of man that battles against adversity and refuses to be discomfited.*

His Last Day

It was the afternoon of Tuesday, January 18, 1966 when after having attended to his daily mail, Dr Prasad was taking tea in his dining room with his younger daughter and a research pupil, Dr T. Singh. The end came suddenly and he collapsed on the table itself even before any medical aid could reach him. Having lived a glorious life, he quit this world at a moment when he had reached the zenith of his glory. May his Soul rest in Peace !

S. R. Sinha

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NOTES

Books, Articles and Talks

(*i*) Prasad wrote several books for school children, thereby bringing to them too the advantages of the ideas and experiences of a seasoned mathematician of the country.

His book on '*Hydrostatics*', meant for the students of the B.A./B.Sc. classes of Indian universities, remained so popular for decades that, in addition to its original English version, it had to be translated into Marathi and Hindi.

(*ii*) He wrote a number of articles on topics of scientific and mathematical interest, particularly a few about the lives of famous Indian mathematicians.

(*iii*) Through his talks to various student organizations, from time to time, he tried to popularize even a difficult subject like Mathematics.

ACKNOWLEDGEMENTS

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G. N. Rangaswamy

RAO BAHADUR GIYARPURAM NADATHUR RANGASWAMI AYYANGAR

(1887–1968)

Foundation Fellow 1935

GIYARPURAM NADATHUR RANGASWAMI AYYANGAR, the well-known pioneer millet geneticist and breeder was born on May 19, 1887 at Madras and died in the same city on November 17, 1968.

PARENTAGE

Rangaswami Ayyangar, affectionately addressed as G. N. R. by his friends and colleagues, was a descendant of *"Nadathur Ammal",* an erudite devotee of *Lord Varadarajaswami* of Kanchipuram, whose portrait is still in the precincts of the Lord's temple. His father, the late N. A. Sunderavaradachari was a Deputy Collector in the Rayalaseema of the then composite Madras State. Rangaswami was the third son of his father's second wife. He lost his father when he was five years old. From his childhood he was greatly influenced by his mother, a gracious lady known for her religious and devotional bent of mind.

SCHOOL AND UNIVERSITY EDUCATION

Rangaswami had his early education at the Teacher's College High School, Saidapet, a suburb of Madras, and after completing his high school studies from this School, he joined the Madras Christian College and later the Presidency College. In 1910, he obtained his B. A. Degree of the Madras University with Botany as the special subject.

PROFESSIONAL CAREER

After spending a year at the Madras Law College, he embarked on his official career in 1911 as a lecturer in Botany at the Pithapur Raja's College, Kakinada (now in Andhra Pradesh). Noting his competence and fluency in English, he was asked by the Principal of the College to teach English also, besides his duties as Lecturer in Botany.

A year later, on the advice of Professor K. Rangachari, the then Economic Botanist at the Agricultural College and Research Institute, Coimbatore, he joined the Institute as an Assistant to the Economic Botanist. With the reorganisation of the Institute, he was appointed Assistant to the Paddy Specialist, the late Mr F. R.

Parnell. Dr K. Ramiah later joined the Paddy Section and was Rangaswami's next junior colleague.

Young Rangaswami's intelligence, initiative and hard work impressed Mr Parnell so much that he was promoted to the Madras Provincial Service and appointed as Assistant Paddy Specialist in 1920. Within a year, he was selected to the newly established Indian Agricultural Service, as its youngest Officer. A separate section for the improvement of millets was created and Rangaswami was appointed to the post of Millet Specialist which he held with distinction until three years before his retirement in 1942 as Principal of the Agricultural College and Research Institute, Coimbatore.

After his retirement from the Government of Madras, he was appointed as Officer on Special Duty by the Agricultural Department of the Government of India to survey and report on the resources for the improvement of Agriculture and Livestock in the Andamans and Nicobar Islands with a view to progressively colonising them. His report provided the base for the subsequent development plans for the Islands. Similarly, his report on *bhajra* cultivation in the arid zones of the Punjab greatly helped to re-orintate the *bhajra* economy in that State. Later, he worked as Professor and Head of the Department of Botany, Andhra University for about three years (1948–51).

Botanical Research and Scientific Contributions

During the short tenure as Assistant to the Economic Botanist, he was in charge of teaching Botany to the students of the Agricultural College and organizing herbarium in the Economic Botany Section.

The Paddy Breeding Station at Coimbatore, a pioneering organization in the history of rice breeding in India, gained importance through the joint endeavour of Parnell, Rangaswami and Ramiah. G. E. B. 24 rice strain which spread rapidly in Madras and other States of India as well as in other tropical rice growing areas of the world was an outstanding contribution of the station. In addition to the spade work done by them in field methodology for testing of varieties and selection of pure lines, the fillip given by the re-discovery of Mendel's laws of inheritance led to the study of morphological traits of the rice plant and their modes of inheritance.

Rangaswami's main contribution was the establishment and organisation of the Millets Breeding Station at Coimbatore in 1921. Alongwith a band of enthusiastic assistants, he made comprehensive studies on the inheritance of several characters in the major and minor millets, more extensively in Sorghum (Jowar), standardised morphological descriptions, evolved genetic symbols and identified linkage groups. Sir John Russel in his review entitled : *The State of Agriculture in India,* has paid rich tribute to Rangaswami's ability. In a personal letter addressed to Rangaswami, the Secretary to the Department of Agriculture, Washington, U.S.A., has stated that "*According to our specialists, you have contributed more to the world's knowledge of genetics and morphology of the Sorghum plant than any other person, past or present. During the long period of your service, you kept the Sorghum research workers of the United States informed regarding the discoveries made by you and your associates. Thus, our workers obtained numerous valuable facts which, otherwise would have*

been learned only through long painstaking research. Often your publications confirmed certain preliminary observations and then established facts without the necessity of elaborate repetition of our experiments. The knowledge to Sorghum genetics contributed by you, supplemented by appreciable but less extensive research in the United States has placed Sorghum Breeding on a highly scientific basis. Applied genetics is being used as extensively in Sorghum Breeding as in the improvement of any crop plant and much more so in most crops. You deserve a large share of the credit for this progress."

Honours and Distinctions

Rangaswami Ayyangar was a Foundation Fellow of the Indian Academy of Sciences, Bangalore, Fellow of the National Academy of Sciences, (India) Allahabad. Indian Botanical Society and Indian Society of Genetics and Plant Breeding. He was also a member of the Botany and Foodgrains Committee of the Indian Council of Agricultural Research. He was a collaborator on the editorial boards of *Science and Culture,* Calcutta, *Current Science,* Bangalore and the *Madras Agricultural Journal.*

He was awarded the title of Rao Bahadur in 1935 and the *Coronation Medal* in 1937. In 1941, he was the recipient of the prestigeous *Brühl Medal,* awarded triennially by the Royal Asiatic Society of Bengal for the most meritorious research in any branch of Botany.

Family Life

As was the custom in those days, Rangaswami was married early to Maduravalli, daughter of Eachambadi Srinivasachari, Deputy Collector and sister of the late Dr E. V. Srinivasan, a prominent eye surgeon in Madras. Rangaswami lost his wife when he was only 31 years old. In 1922, he married again. Through his first wife he had one son and two daughters and by the second wife, two sons and four daughters. His first son, Dr G. N. Rajagopalan, has distinguished himself as an eminent E. N. T. Surgeon at Coimbatore and the second, Mr G. N. Ananthachari, a Chartered Accountant is a partner in Fraser and Ross at Madras. Dr G. N. Srinivasan, the third son, is a general Medical Practitioner attached to the Health Department, Melbourne, Australia. The late Mr S. Narasimhachari, an able criminal lawyer at Coimbatore, was the husband of his first daughter. The second daughter's husband, Mr V. S. Desikan, now settled in Lucknow is a retired Chief Engineer, Housing Board, Lucknow. The next daughter's husband, the late Mr T. M. Rama Iyengar, a graduate in Agriculture, from the Madras University was Director, Metal Box India Limited. The fourth daughter, Dr G. N. Seetha is now a Professor of Pathology in Government Medical College, Chengalpet, Tamil Nadu. Mr D. P. Rangaswami, the husband of the fifth daughter, is the Managing Director, Southern Ware House, dealing with U-Foam etc. The last daughter is married to a Mining Engineer at Dhanbad. During his life time, Rangaswami suffered the loss of his first daughter's husband and the husband of Dr Seetha and he bore these with philosophical equanimity.

Personal Qualities

Rangaswami was energetic and active and idleness was anathema to him. He was very scrupulous about cleanliness both in private and official life. Any one visiting the Millets Breeding Station at Coimbatore, during his tenure, was impressed by the clean fields and roads without any extraneous matter, be it weed in crop fields or trash on the roads. The laboratory and office were always tidy and he could not brook even a speck of dust on any piece of furniture.

Rangaswami was a strict disciplinarian and his staff respected him and collaborated willingly in research activities. He was a voracious reader interested in literature, astronomy and history and could speak fluently with imagination and introspection. He was a shining example to his associates of unceasing activity and orderly and methodical approach to research problems. Disciplinarian though he was, a man of warmth and goodness. He was fond of animals, especially dogs and cows. He used to have pet dogs of various breeds and was a judge in the Kennel Club at Coimbatore. When he could not keep cows in his official residence, he built his own house in R. S. Puram at Coimbatore so that he might have the pleasure of tending cows and calves. All in all, he was an outstanding personality.

Acknowledgement

In the preparation of this memoir, Dr G. N. Seetha gave details regarding Rangaswami's family and personal life. Mr R. Appadurai, Professor of Botany, Tamil Nadu Agricultural University, Coimbatore, supplied the list of Rangaswami's publications, and to both of them thanks are due.

N. Parthasarathy

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APPADVEDULA LAKSHMI NARAYAN

(1887–1973)

Foundation Fellow

Birth, Parentage and Childhood

Appadvedula Lakshmi Narayan was born in 1887 in an orthodox brahmin family to Appadvedula Vyasulu and to Mahalakshmi in the village Mukkamala in Konaseema of East Godavari District of Andhra Pradesh (then Presidency of Madras). His parents were pious Hindus, well versed in Vedic culture and customs.

Departing from his family tradition of studying Vedas and Sastras, Dr Narayan took to English education from his childhood. He studied upto matriculation in the higher secondary school at Kothapeta, a taluk centre very near his place of birth. From the very beginning of his educational career, he developed keen interest in the study of science in preference to humanities and continued his studies in the Government Arts College, Rajahmundry and passed the B.A. degree with physics as his main subject, from the University of Madras, which was then the only University for the whole of South India.

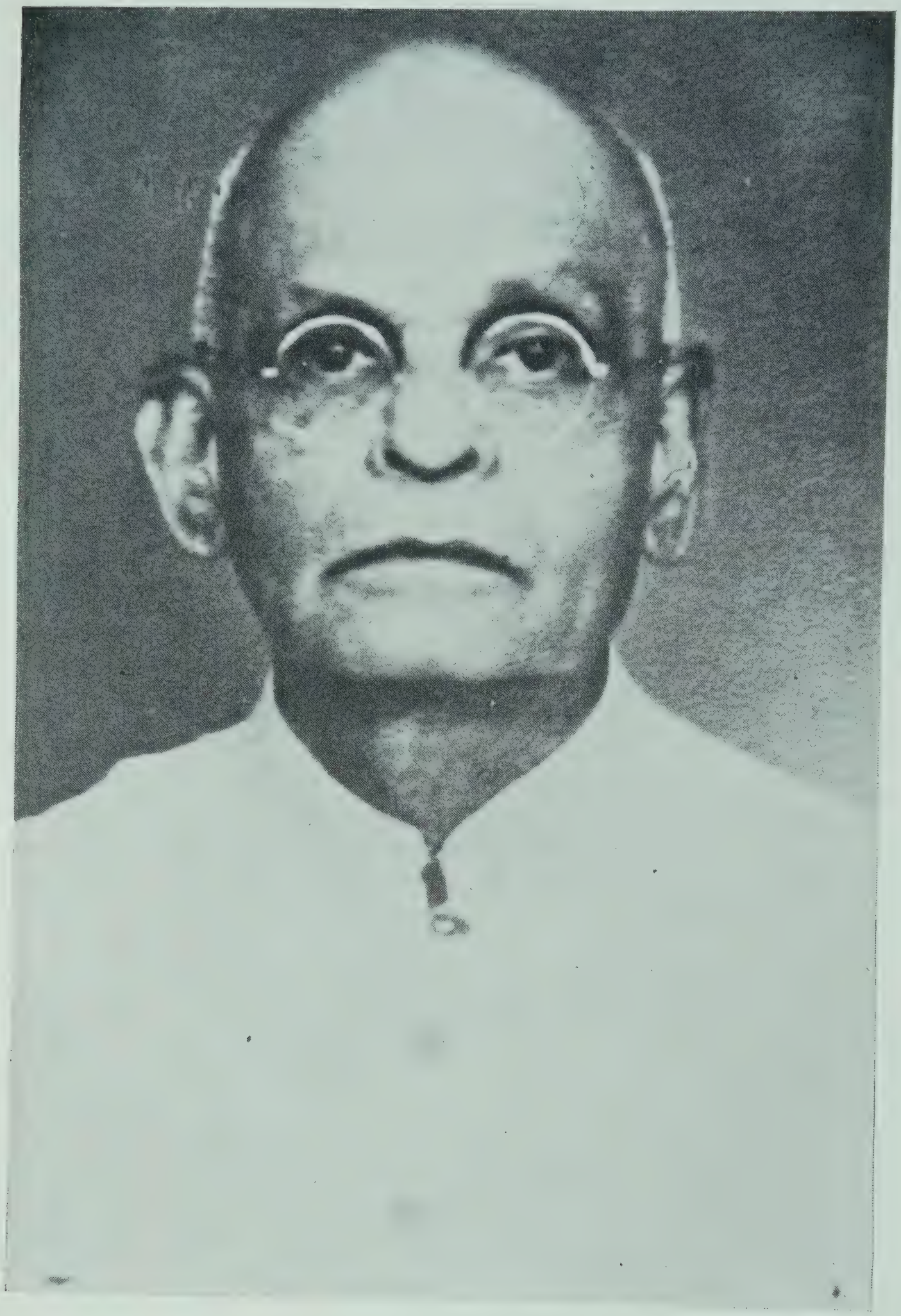
Not satisfied with a pass degree, Narayan studied privately for the M.A. degree in physics, of the Madras University and passed the same in 1914. He then joined as Lecturer in Physics in Maharaja's College of Vizianagaram, one of the few degree colleges in Madras Presidency at that time. He was the first M.A. in Physics among the few from Andhra who took that degree from the University of Madras.

When Narayan joined as Lecturer in Physics in Maharaja's College, Vizianagaram, Physics was taught only upto the Intermediate level but at his initiative and with his efforts, he was able to obtain affiliation for the degree course in physics of the University of Madras in 1918 in that college.

With only four students (for which number affiliation was granted by the University of Madras) for coaching upto the B.A. degree (there was no B.Sc. degree course at that time in the University) and with the meagre equipment available in the college, he trained the first batch of students for the degree examination of 1920. In this batch was the late Dr K. Rangadhama Rao who later became a pioneer in India in spectroscopic research. The writer of this memoir was in the third batch of students.

Research Career at Vizianagaram

Since the start of his teaching career in 1914, Dr Narayan took keen interest in scientific developments in Great Britain and the United States. With the meagre



A. L. Narayan

grants for library he was getting, he could save something for purchase of journals like *Nature*, *Science Abstracts*, *Proceedings of the Royal Society of London*, *Philosophical Magazine*, *Proceedings of the Physical society of London* and popular scientific journals like *Scientific American* etc. These journals helped to create in him an aptitude for research in physics.

At the same time, Dr Narayan got his inspiration from eminent physicists of the University of Calcutta, the late Professor Sir C.V. Raman and Professor M.N. Saha. Being in the Post-Graduate College of Science and Technology of that University, both these scientists had enough facilities for research provided by the then Vice-Chancellor of the University, the late Sri Asutosh Mookerjee. But Dr Narayan being in a degree college, was handicapped for want of equipment for research. But as he was tenacious and anxious to start with the meagre resources available, he researched in the field of Spectroscopy. From the grants of the laboratories for the graduate course, he could save enough to purchase two instruments for research *viz.*, one small and one medium quartz spectrographs and with these he began his work on line spectra and their analyses both in the emission and absorption types.

Dr Narayan rigged up a small workshop in which he could make his own tools and equipment necessary for his research. He did his own glass-blowing work for making discharge tubes for gases. He purchased a single-stage vacuum pump and a mercury diffusion pump for high vacuum necessary in several cases. For exciting arc-spectra, he used a dynamo coupled with a set of batteries necessary for D.C. For spark spectra requiring high voltages of the order of 15,000 volts he made use of an induction coil available in the laboratory.

What was remarkable in Dr Narayan was his resourcefulness. He could develop single-handed a research laboratory, which ranked among the best in India and enabled him to produce original work. All this he did in addition to teaching work for the degree classes which demanded much of his time. His hunger for research consumed all his evenings till late in the night.

Starting in 1921 with some general topics like coupled vibrations of a double-pendulum, mechanical oscillations of magnetically coupled oscillating circuits, modified form of double slit spectrophotometer, surface tension of soap solutions at different concentrations, sounds of splashes etc., Dr Narayan began concentrating on spectroscopy in which he specialised during the period 1923–30.

With the original papers published by him during 1922–24, he submitted his thesis for the degree of Doctor of Science of the University of Madras. He was the first D.Sc. in physics of that University. His work was much appreciated by C. V. Raman and M. N. Saha who were, at that time, foremost in the field of Physics in India and both of them gave him a lot of encouragement in his advanced studies in the field of spectroscopy.

It was at this time in 1924 that the late Dr K. Rangadhama Rao who later gained the distinction of being one of the foremost spectroscopists of India, joined Dr Narayan as a research scholar. Both of them worked tenaciously to build up a first rate spectroscopic laboratory second to none in the country.

They had then with them a constant deviation spectrograph, a small quartz spectrograph and a medium quartz spectrograph. All these were of low dispersion

and low resolving power. At this stage of their work, they required an instrument of high dispersion and high resolving power, which they could not afford. So, Ranghadhama Rao was sent to Calcutta, where a ten-foot concave grating was available in the Indian Association for the Cultivation of Science of which C.V.Raman was Director and with the facilities provided there, they could further extend their work on analysis of spectra in the visible and ultraviolet regions.

But the analysis could not be complete without extending the study of the far ultraviolet and vacuum regions. No vacuum grating spectrograph was available in India at that time. Dr Narayan purchased a grating for the vacuum region and constructed a spectrograph of his own design. The next problem was procurement of the special Schumann photographic plates suitable for this instrument. They were not easily available anywhere in the world and even when available, they were so delicate that they were liable to damage during transit. But Narayan was so resourceful and so determined to overcome all handicaps that he developed the technique of manufacturing these special plates and succeeded in using the instrument to extend his investigations to the vacuum region of spectra.

The series in line spectra which Dr Narayan analysed, had to be confirmed by study of the fine structure of these lines. So he purchased interference spectroscopes like the Lummer-Gerhcke plate and Fabrey-Perot-interferometer and in conjunction with the constant-deviation spectrograph, he could photograph the fine structure of these lines and thus confirm the analysis of the series in line spectra of several elements. In this work he had the assistance of K. Rangadhama Rao.

No work in spectroscopy is complete without covering the entire range of the spectrum comprising the visible, ultraviolet and infrared regions. So Dr Narayan began to equip his research laboratories with the components necessary for work in the infrared. This, however, had to be left incomplete because he was called to occupy the post of Assistant Director at the Solar Physics Observatory at Kodaikanal, in 1929.

Narayan's Work at Kodaikanal Observatory

At Kodaikanal, Dr Narayan had much better facilities in respect of scientific equipment and resources. So he started more extensive and intensive work with a view to make the institution a centre of spectroscopic research. The observatory had already become famous for observations on solar and stellar physics through the work of the great Astronomer John Evershed F.R.S., who was its Director for many years. Dr Narayan began recruiting research scholars and scientists both from India and abroad and made it a vigorous centre.

In recognition of his contributions Dr Narayan was promoted as Director of the Observatory. He was the first Indian to occupy the post.

During his regime, the library was enlarged by the acquisition of a large number of books and periodicals on astronomy, mathematics, physics, geophysics, statistics and allied sciences. He also expanded the workshop and spent considerable time in improving its working. The observatory acquired its own generator for supply of electrical energy to the laboratories, the library, the offices and to the rest of the campus.

During the Second World War, particularly after the threat to India of aggression from the Japanese, some of the senior members of his staff were shifted for meteorological work in connection with the war effort. There was interruption of research work to some extent, but Narayan could not rest contented, and carried on his research work with the meagre staff remaining with him.

After the War, the Government of India appointed a Committee for the post-war development of astronomy and astrophysics in the country, with particular reference to the expansion of the activities of the Kodaikanal Observatory, with the later Professor M. N. Saha as Chairman. Dr Narayan was an active member of the Committee and was instrumental in launching the scheme of expansion of the Observatory.

He retired from the post of Director in 1947 at the age of 60.

Narayan, a Man of Social Importance

At Kodaikanal, he had taken keen interest in the Civic life of the Hill Station. He was an active member of the Boat Club, the Kodaikanal Fellowship and the Indian Club and took part in all social activities of the small township, which was the summer resort for the elite of South India, next only to Ooty. Ooty, which was the summer capital of the Government of Madras was crowded and busy and hence, people preferred Kodaikanal at an elevation of 7000 feet above sea level. Most of them visited the Observatory which was 1000 feet higher up the town. Dr Narayan thus came in contact with eminent lawyers, businessmen, industrialists, professors and politicians. He thus became a popular figure among them.

He also encouraged his staff to actively participate in the civic activities of the town, as a change from the isolation of their place of daily work, which was far away from the township. He took keen interest in gardening and maintained a beautiful garden both in the Observatory campus as well as in his bungalow nearby. He was a strict disciplinarian in office as well as at home and very hardworking. At the same time, he was generous and sympathetic and treated his young assistants as members of his family.

During his tenure of office at Kodaikanal, he was in constant touch with centres of learning in South India. He was a member of the Syndicate, Senate, Academic Council and Boards of Studies in Physics of Madras and Andhra Universities and evinced keen interest in their academic advances, particularly in the sciences. Indeed, he played an important role in the foundation of the Andhra University in 1926 and later in the development of University courses in Arts and Sciences there. He was continually active in the several administrative and academic bodies of the Andhra University and later became its Vice-Chancellor.

Narayan : An Eminent Administrator

Having retired as Director of the Solar Physics Observatory at Kodaikanal, he wanted to settle down in Madras and lead a peaceful life there. But that was not to be. The Rajah Saheb of Vizianagaram, who got acquinted with Dr Narayan during his frequent visits to Kodaikanal, offered him the post of the Principal of Maharajas College, Vizianagaram which was founded by his forefathers as early as the eighties

of the last century and of which he was the Chairman of the Board of Trustees. This was the same college, where Narayan had started his teaching career in 1914 and had done most of his early research for fourteen years. He accepted the offer and thus began his administrative activity in the field of education. His administration was marked by progressive thinking, punctuality and discipline and he made the College a model for the Andhra University area.

As ex-officio member of the Senate of the Andhra University, from which body he was elected to the Syndicate, he made distinctive contribution to the advancement of learning in the University, particularly in the sciences. He retired as Principal of Maharajas College, Vizianagaram after a distinguished service for nearly a decade. During this period, he was responsible for starting two additional colleges, one for Teachers' Training and the other for Girls both of which were located in Vizianagaram.

Narayan as Vice-Chancellor

Dr Narayan settled down at Visakhapatnam hoping to spend the rest of his life in peace and quiet. But soon he was called upon to take up the responsible postion of the Vice-Chancellorship of the Andhra University, rendered vacant by the late Dr V. S. Krishna who was appointed as Chairman of the University Grants Commission.

At 74 years, Dr Narayan was still very active. He attended to his duties regularly and his work was systematic and thorough. His door was always open to all categories of staff and students. At the same time, he was a strict disciplinarian, and did not hesitate to enforce necessary discipline where and when required. This caused a certain amount of displeasure among some sections of the staff and students, but he never deviated from the path of discipline to gain their goodwill, though at heart he was kind and helpful to all. In the matter of recruitment of staff for the various faculties of the University he was strictly constitutional and he remained unswayed by any pressure, much to the chagrin of the powers that be.

Dr Narayan proved to be a worthy successor to his eminent predecessors C. R. Reddy and S. Radhakrishnan, who made the Andhra University as one among some of the best universities in India.

In the matter of advanced research in both Arts and sciences, he encouraged talented young men to take up doctoral and post-doctoral researches in their respective branches of learning under the guidance of eminent professors. Being himself a devotee of scientific research during the major part of his life, he fully understood the importance of research in the academic functions of a University. He was instrumental in establishing a large number of research scholarships from grants procured from the University Grants Commission, the Council of Scientific and Industrial Research and similar All India institutions.

Dr Narayan could thus consolidate the functioning of the University in the academic and administrative aspects. He finally retired as Vice-Chancellor in 1966, with full satisfaction of serving the University for five years, and for a continuous period of forty years in various capacities.

He finally retired from active life and settled down at Visakhapatnam at the ripe old age of 79. He died on March 7, 1973 at Madras, in the house of his second son A. L. Rama Rao. He is survived by his wife, two sons and four daughters.

Family and Private Life

Dr Narayan was head of quite a big family. At an early age he had married Srimathi Seshamma. They had three sons and four daughters. He had two major calamities during his life time. The first was the death of his eldest daughter's husband, Dr A. Subba Rao who was working as Soil Physicist of the Government of Madras at a very early age, in 1954. This was followed by the demise of his eldest son, Dr A. L. Sundara Rao, who was working as Special Officer to the Central Leather Research Institute at Madras.

Dr Narayan bore these calamities with courage and fortitude. He continued his life's mission of scientific work and administrative service to the Nation without interruption.

Honours and Distinctions

Dr Narayan was Fellow of the Institute of Physics, London, Fellow of the National Institute of Sciences, India (presently, Indian National Science Academy) and President of the Physics Section of the Indian Science Congress at Benares. As a member of the Andhra Pradesh Planning Commission, he contributed considerably to Scientific education in the Andhra area. He was the receipient of the '*Maharaja of Travancore Curzon Memorial Prize*' in recognition of his researches in Science.

Acknowledgements

The author of this memoir acknowledges with thanks the help rendered by Dr A. Bhanumati in preparing the list of publications of Dr Narayan during the period 1921–30, and to Sri G. K. Money for helping him with information regarding Dr Narayan's activities at Kodaikanal Observatory and his publications there.

I. Ramakrishna Rao

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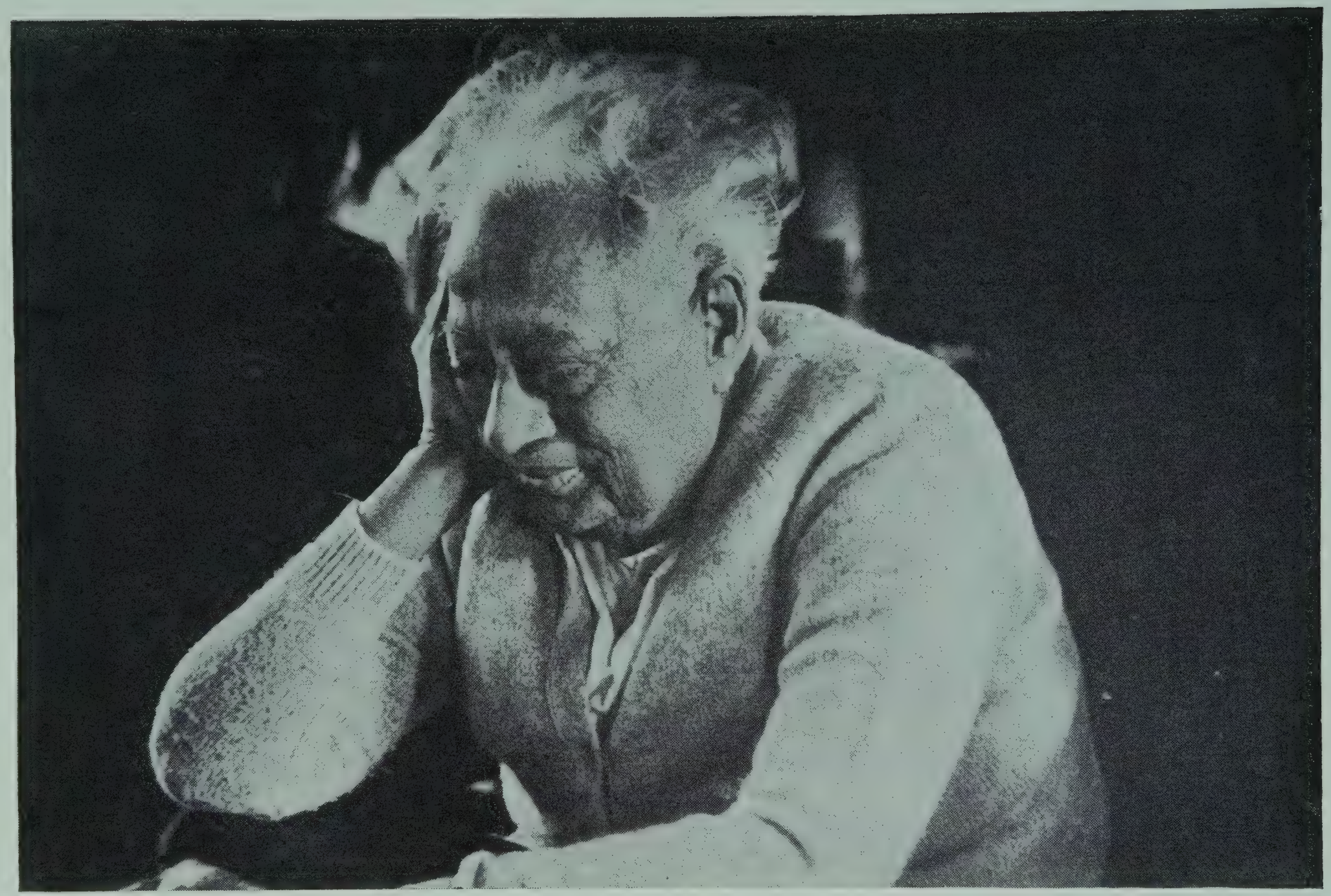

SATYENDRA NATH BOSE

(1894–1974)

Foundation Fellow 1935

Birth, Parentage and Childhood

Satyendra Nath Bose was born on the New Year's Day, January 1, 1894, in Calcutta. His ancestral home was located in the village Bara Jagulia, in the District of Nadia, about 48km from Calcutta.

Satyendra Nath's father, Surendra Nath Bose, had a keen fascination for mathematics. In his professional career, he became a qualified accountant and held responsible positions in the East Indian Railway. He lived upto the ripe old age of 96 years. He breathed his last on June 2, 1964, with his mental faculties fairly alert. Satyendra Nath's mother, Smt. Amodini Debi, had died earlier, in 1939. Her life was a ceaseless struggle against ill-health and inadequate income to maintain a middle class home. Satyendra Nath was her only son and she had after him six daughters in succession. The parents were proud of their son, and the son was no less devoted to his parents.

Formative Influences on the Young Scientist

During his boyhood, it was the spirit of the times that moved him most. The later years of the nineteenth century witnessed a new awakening in Bengal. Politically and socially, India was making its entrance into the modern age. He was a school boy when he came under the impact of what is now known as the Swadeshi Movement in Bengal. A significant feature of the Movement was the growth of a new spirit of self-help and emphasis on building up of Indian industries, and of art and culture. This became evident in the annual sessions of the Hindu Mela. The trend reached its peak during the Industrial Exhibition of 1896. Swadeshi stores were opened and a ceaseless campaign for Swadeshi goods was started. Satyendra Nath's father was one of the leaders of the Movement. He was a founder of the Indian Chemical and Pharmaceutical Works, which went into production about the same time as Sir P. C. Ray's Bengal Chemical and Pharmaceutical Works. Meanwhile the national movement of the Indian National Congress had started. It fired the younger generation with a spirit of intense nationalism. Imbued with this spirit, talented young men felt an inner urge to forge ahead and to excel in their respective fields of specialisation. Satyendra Nath belonged to this generation.

School and University Education

Satyendra Nath's schooling began at the age of five. At first he was put in the Normal School, which was close to their home. It was the same school where Rabindra Nath Tagore had been a student for a short period. Later on, when the family moved to their own house at Goabagan (22, Iswar Mill Lane, Calcutta), he was admitted to the neighbouring New Indian School. Satyendra Nath's father was anxious to put his son into an even better school where his talents would be sharpened by keener competition. And so, in the final year of school, he was admitted to the Hindu School which had a hoary tradition. Its mathematics teacher, Upendralal Bakshi, was a legendary figure. He was quick to recognise the signs of genius in the boy and found in him an ideal pupil. Once he gave him 110 marks out of 100 in a test examination. When taken to task by the Headmaster for his crazy behaviour, the teacher replied : "Satyen had succeeded in the allotted time in correctly solving all the questions without excluding any of the alternatives." His enthusiastic forecast about Satyen Bose's future career was that he would one day be as great a mathematician as "Laplace or Cauchy." Satyendra Nath was due to sit for his entrance examination in 1908 at the age of 14 years. But unfortunately, he was down with an attack of chicken pox just two days before the examination. As a result he had to remain in Hindu School for one more year. He used the opportunity to study advanced mathematics and sanskrit classics. In the next entrance examination of 1909, Satyen stood fifth in order of merit. He next joined the Intermediate Science course at the Presidency College, Calcutta, where he came under the tutelage of illustrious teachers like Jagadish Chandra Bose and Prafulla Chandra Ray. According to Sir P. C. Ray : "In that memorable year, some members of the brilliant group of students, who were afterwards destined to play a conspicuous part in notable scientific research took their admission in the Presidency College." The brightest among them was Satyendra Nath Bose. His fellow-students were Jnan Chandra Ghosh, Jnanendra Nath Mukherjee, Nikhil Ranjan Sen, Pulin Bihari Sarkar, Maniklal De, Sailendra Nath Ghose and Amaresh Chakrabarti. Meghnad Saha came from Dacca and joined the Presidency College two years later. Prasanta Chandra Mahalanobis, Nil Ratan Dhar and Sisir Kumar Mitra were a few years senior to this group.

In the Intermediate Science examination of the Calcutta University in 1911, the first five places (in order of merit) were occupied by Satyendra Nath Bose, Maniklal De, Meghnad Saha, Jnan Chandra Ghosh and Pranakrushna Parija respectively. Satyen had physiology as the fourth subject in his I. Sc. examination, in which he scored 100 marks out of 100.

In the B. Sc. class, Satyendra Nath Bose, Nikhil Ranjan Sen and Meghnad Saha opted for Mixed Mathematics, while Jnan Chandra Ghosh, Janendra Nath Mukherjee and Pulin Bihari Sarkar opted for Chemistry. Sailendra Nath Ghose, Amaresh Chakrabarti and Snehamoy Dutta studied Physics while Pranakrushna Parija took up Botany. It is interesting that five of the above group of fellow-students at the Calcutta University became, in quick succession, General Presidents of the Indian Science Congress Association.

No. 1

CALCUTTA UNIVERSITY.

M. Sc. Marks.

The following are the marks obtained by Satyendranath Bose

No. 1 Presidency *College at the* **M. Sc. Examination 1915**

in Mixed Mathematics.

		Theoretical									Applied								
		First Paper.	Second Paper.	Third Paper.	Fourth Paper.	Fifth Paper.	Sixth Paper.	Seventh Paper.	Eighth Paper.	Total.	First Paper.	Second Paper.	Third Paper.	Fourth Paper.	Fifth Paper.	Sixth Paper.	Seventh Paper.	Eighth Paper.	Total.
		98	85	100	89	88	94	98	84	736									

GRAND TOTAL.	
Minimum for a	*
First Class	*
Second "	*
Third "	*

SENATE HOUSE.

The 15-9-1915.

P. Bakhi

Registrar.

C. U. Press—Reg. No. 163 11-11-09.

In the B. Sc. Honours examination in Mathematics in 1913, Satyendra Nath stood first, Meghnad second and Nikhil Ranjan third, all in first class. The same result was repeated in the M. Sc. Mixed Mathematics examination in 1915. Satyendra Nath stood first and Meghnad Saha stood second in first class. Nikhil Ranjan did not appear at the M.Sc. examination in 1915 due to illness. However, he topped the list of successful cadidates next year. It is said that the marks secured by Satyendra Nath Bose in his M.Sc. (Mixed Mathematics division) examination created a new record in the annals of the Calcutta University, yet to be surpassed. A photostat copy of the original marksheet is exhibited on the facing page.

Private Life and Reminiscences

Marriage, Wife and Children

In 1914, at the age of 20, while still a student of the Post-graduate M.Sc. class, Satyendra Nath Bose was married to Ushabati Ghosh, the only daughter of Jogindranath Ghosh, a renowned medical practitioner of Calcutta. According to the social custom of those days, Bose had no say in the choice of the bride. It was left entirely to his mother to select her daughter-in-law. Young Bose, however, objected to the one social evil, viz., the acceptance of dowry. He agreed to marry the girl of his mother's choice only on condition that they would not demand any cash dowry from the girl's family. This was, of course, agreed to by both parties.

Ushabati was eleven when she was married. She had gone to school, first at the Nivedita School, then at the Mahakali Pathsala. The enthusiastic husband started giving her lessons in English.

They had nine children. Two of them (a boy and a girl) died in their infancy. Professor Bose left behind him his surviving widow, two sons and five daughters. The elder son Rathindra Nath Bose is an electrical engineer while the younger, Ramendra Nath Bose joined an electronics engineering firm. Bose took good care that most of his daughters had graduated before they were married.

Languages

That he should write English of real power may perhaps be deemed natural enough for a scientist of his varied interests and artistic bent of mind. His presidential address as General President of the Indian Science Congress in 1944 is a model of chaste scientific prose. But it is indeed remarkable that he should be equally at home since his student days, with French, German and Italian languages. It was perhaps Hugo, Goethe or the Sanskrit classics, which gave him inspiration and pleasure. In his youth he was associated with Pramatha Chaudhuri and Sudhindranath Dutta and regularly attended the "*Sabuj Patra*" conventions. Here he came under the influence of Rabindra Nath Tagore, whose writings cast a spell over him.

Bose had always been alive to the problem of propagation of science among the people. Soon it became clear to him that the reason why science in our country was not able to make progress was the barrier of a foreign language through which it was taught. In 1948, he founded the *Bangiya Bijnan Parishad* (Science Association of Bengal) for popularising science in Bengali. The *Parishad* has since been publishing

Jnan O Bijnan (Knowledge and Science), a popular monthly in Bengali on Science. It has now also a building of its own, named "Satyendra Bhavan" after his death. The *Parishad* publishes school and college text-books on science in Bengali and also arranges popular lectures and seminars, conducted in Bengali. During his speeches at the *Parishad,* Bose could express himself in elegant Bengali without the intervention of a single foreign word. He had also started teaching post-graduate classes on Relativity at the Calcutta University in colloquial Bengali.

Early Teaching and Research (1915–20)

In 1915, a batch of brilliant and enthusiastic students, after completion of their M.Sc. course, approached Sir Asutosh Mookerjee, the then Vice-Chancellor of the Calcutta University, for advice regarding research and higher studies. He recognised their talents and engaged them to run the newly started post-graduate classes in Physics and Applied Mathematics in the University College of Science, Calcutta. Satyendra Nath joined the university as a research scholar in 1916 and started his studies in the theory of Relativity. Next year, both he and M. N. Saha were appointed lecturers in Physics and Applied Mathematics departments. In the words of Bose : "We took upon ourselves the teaching of post-graduate students. Saha taught Theory of Heat and Thermodynamics and Spectroscopy in the Physics Department and Hydrostatics in the Mathematics Department. I was more amphibious, teaching both Physics and Applied Mathematics quite regularly. On me fell the task of teaching General Physics and giving all entrants suitable introduction to Mathematical Physics, teaching them Differential equations, Harmonic analysis etc. I also taught Elasticity and Relativity in the Mathematics Department."

Both of them had accepted the challenging job of developing the University College of Science, Calcutta, into a centre of advanced learning of international standards. It was an exciting era in the history of scientific progress. The quantum theory had appeared and new significant results started pouring in. According to Oppenheimer : "For those who participated, it was a time of creation. There was terror as well as exaltation to their new insight." Bose's research work in Physics covers a wide range of problems, theoretical and experimental alike. His first important contribution in theoretical physics is a paper jointly with M. N. Saha on the equation of state. It was entitled : "On the influence of the finite volume of molecules on the equation of state." It was published in the *Philosophical Magazine* in 1918. The equation of state proposed in the paper is generally known as Saha-Bose equation of state. This was followed by two papers, one on "The Stress equations of Equilibrium" and the other "On the Horpolhode." They were published in the *Bulletin of the Calcutta Mathematical Society* in 1919. During the following year, he published two more papers in the *Philosophical Magazine,* viz., "On the equation of state" (jointly with Meghnad Saha) and "On the deduction of Rydberg's law from the quantum theory of spectral radiation." During this period, the Calcutta University also published a booklet entitled : "*The Principle of Relativity,*" which contained original papers by A. Einstein and H. Minkowski, translated by M. N. Saha and S. N. Bose, with a historical introduction by P. C. Mahalanobis.

Professional Career

Bose at Dacca and his First Visit to Europe (1921–26)

During 1920's, the situation in the Department of Physics of the Calcutta University was rather uncomfortable. Too many able scientists were crowded together and laboratory accommodation, technical resources and equipment were all inadequate. With the migration of some of the members of the teaching staff to other universities, there was some relief. The first physicist to migrate was Satyendra Nath Bose. He joined the Dacca University, which was founded in 1921, as Reader in Physics. While Bose did much teaching and guiding students in their practical classes, his main interest was theoretical physics. And so, most of his spare time was devoted to a critical study of original papers of Planck, Einstein, Böhr and Sommerfeld. This was a period of intense study and preparation for Bose, who used to impress upon his students : "*Never accept an idea as long as you, yourself, are not satisfied with its consistency and logical structure on which the concepts are based. Study the Masters. These are the people who had made significant contributions to the subject. Lesser authorities clearly bypass the difficult points.*"

Background of His Principal Work (1924)

S. N. Bose had carefully studied Max Planck's book entitled "*Thermodynamik und Wärmestrahlung*" a copy of which had been presented to him by Dr D. M. Bose. He knew about phase space and Boltzmann Statistics from Gibbs' book : "*Vorlesungen über Gastheorie.*" He also knew about Einstein's deduction of Planck's formula and how he had never been satisfied with the derivation of this quantum law: he always kept on coming back to it. Planck's condition ran counter to the classical ideas. Planck was aware of the difficulties, but he had never been able to resolve them. He wanted to reconcile his theory with the classical theory. He had the idea of having continuous absorption and discontinuous emission. In order to make these things clear to his students, Bose wanted to solve the difficulty in his own way. It was sometime around March 1924 that Saha happened to visit Dacca University, in connection with M.Sc. practical examination. He stayed with Bose who told him about the difficulties about the derivation of Planck's law, which he encountered while teaching his post-graduate students. He saw the need for a derivation without inner difficulties. Saha drew his attention to certain aspects of equilibrium between radiation and electron gas and to a paper by Einstein and Ehrenfest (1923) published in *Zeitschrift für Physik*. Saha also informed him that Pauli (1923) had utilised Einstein's (1917) idea. The difficulty in Pauli's work was that in order to apply the quantum condition, one had to know exactly what was going to happen afterwards. Saha pointed out these difficulties to Bose.

S. N. Bose was thus induced into a careful study of Einstein and Ehrenfest (1923), Compton (1923), Debye (1923) and Pauli (1923). From these studies, Bose learned about the existing status of Planck's radiation law. The themes of his following two papers on the statistics of radiation grew out of this inquiring study.

Bose's First Major Paper

Bose set about thinking deeply and "spending sleepless nights" about the radiation problem. Next he took the crucial step in the identification of blackbody radiation as a photon gas. He showed that the photons had a startlingly "new" property of being strictly identical. This led to a new expression for the thermodynamic properties of an assembly of photons in contrast to what one would have calculated on the then accepted basis, the so-called Maxwell-Boltzmann statistics. But with the "revolution" that Bose introduced into the counting process one obtains the correct thermodynamics of the photon gas. And that one step was the basis of a new synthesis between the wave and particle properties of photons; and, with it, the foundation of quantum field theory.

Bose communicated this paper to the *Philosophical Magazine* in England. Unfortunately, no acceptance letter was received by him for a long time. And so, he sent a duplicate copy of the manuscript, which was entitled "Planck's law and light quantum hypothesis," to Einstein in Berlin, with a request to have it translated into German and published in the *Zeitschrift für Physik*. He wrote :

Physics Department
Dacca University

Dated, the 4th June 1924.

Respected Sir :

I have ventured to send you the accompanying article for your perusal and opinion. I am anxious to know what you think of it. You will see that I have tried to deduce the coefficient $8\pi\nu^2/c^3$ *in Planck's Law independent of classical electrodynamics, only assuming that the elementary regions in the phase-space has the content* h^3. *I do not know sufficient German to translate the paper. If you think the paper worth publication I shall be grateful if you arrange for its publication in* Zeitschrift für Physik. *Though a complete stranger to you, I do not feel any hesitation in making such a request. Because we are all your pupils though profiting only by your teachings through your writings. I do not know whether you still remember that somebody from Calcutta asked your permission to translate your papers on Relativity in English. You acceded to the request. The book has since been published. I was the one who translated your paper on Generalised Relativity.*

YOURS FAITHFULLY
Sd/- S. N. BOSE

(A facsimile of the above letter in Bose's own hand writing is shown in the plate on the facing page).

Einstein acknowledged Bose's letter and the manuscript in a hand-written post-card, stating that he regarded the paper as an important contribution and that he will have it published. As a matter of fact, Einstein immediately translated Bose's paper into German and added the following note at the end. *Comment of the translator* :

PHYSICS DEPARTMENT.
Dacca University.

Dated, the 4th June 1924.

Respected Sir. I have ventured to send you the accompanying article for your perusal and opinion. I am anxious to know what you think of it. You will see that (I have tried to deduce the coefficient $8\pi\nu^2/c^3$ in Planck's Law independent of the classical electrodynamics,) only assuming ~~that~~ ~~finite~~ that the ultimate elementary regions in the Phase space has the finite h. I do not know sufficient German to translate the paper. If you think the paper worth publication. I shall be grateful if you arrange for its publication in Zeitschrift für Physik. Though a complete stranger to you, I do not feel any hesitation in making such a request. Because We are all your pupils though profiting only by your teachings through the Your writings. I do not know whether you still remember that Somebody from Calcutta asked your permission to translate your papers on Relativity in English. You acceded to the request, the book has since been published. I was the one who translated your paper on Generalised Relativity

Yours faithfully
S. Bose

"Bose's derivation of Planck's formula appears to me to be an important step forward. The method used here gives also the quantum theory of an ideal gas, as I shall show elsewhere."—A. EINSTEIN

Bose's paper, translated by Einstein under the title, "Planck's Gesetz und Lichtquantenhypothese, was received by the *Zeitschrift für Physik* on July 2, 1924 and was published in its issue of August 1924. After Bose's paper came an avalanche of developments, the extension of Bose's theory to particles of arbitrary mass and non-zero chemical potential by Einstein (1924, 1925) : the Fermi(1926)-Dirac(1926) statistics for electrons, the quantization of the electromagnetic field by Heisenberg and Pauli (1929, 1930), and quantum electrodynamics by Dirac (1927, 1935).

Both Bose's theory, including Einstein's extension, and Fermi's theory were essentially statistical theories and dealt with complexions of the field. The actual construction of the wave functions which are symmetric and antisymmetric in the many particle labels was done by Dirac (1927). To find the relation between particle type and the statistics which it obeyed was left to Pauli (1936, 1940), who showed that integral spin particles obeyed Bose statistics and half integral spin particles obeyed Fermi statistics. In modern relativistic quantum field theory, the spin-statistics theorem involving Bosons and Fermions is one of the most fundamental of results.

The applicational possibilities of quantum statistics were clearly demonstrated by Sommerfeld (1928), by introducing Fermi-Dirac statistics to metal physics. In the case of an ideal Bose gas with non-zero chemical potential, there is a critical temperature, below which a finite fraction of gas condenses into a single quantum state. This condensed phase discovered by London (1938) should exhibit superfluid properties. London also suggested that superfluid Helium should be related to this Bose-Einstein condensation phenomenon. Indeed Bose's work stands out as one of the central columns supporting the edifice of modern physics.

Bose, however, did not realise the importance of the immediate impact of this paper. He said to Mehra (1975) later : *"I had no Idea that what I had done was really novel. I thought that perhaps it was the way of looking at the thing. I was not a statistician to the extent of really knowing that I was doing something which was really different fom what Boltzmann would have done from Boltzmann statistics. Instead of thinking of the light quantum just as a particle, I talked about these states. Somehow, this was the same question the at Einstein asked when I met him. How had I arrived at this method of deriving Planck's formula ? Well, I recognised the contradictions in the attempts of Planck and Einstein, and applied the statistics in my own way, but I did not think that it was different from Boltzmann statistics."*

Bose's Second Principal Paper on Radiation Theory

Just eleven days after sending his first paper and letter to Einstein, Bose sent him another paper with a covering letter.

He wrote :

Physics Laboratoroy
Dacca University
Dacca, India,
15*th June*, 1924

Respected Master :

I send herewith another paper of mine for your kind perusal and opinion. I hope my first paper has reached your hands. The result to which I have arrived seems rather important (to me at any rate). You will see that I have dealt with the problem of thermal equilibrium between Radiation and Matter, in a different way, and have arrived at a different law for the probability for elementary particles, which seems to have simplicity in its favour. I have ventured to send you the type-written paper in English. It being beyond me to express myself in German (which will be intelligible to you). I shall be glad if its publication in Zeitschrift für Physik *or any other German journal can be managed. I myself know not how to manage it. In any case, I shall be grateful if you express your opinion on the papers and send it to me at the above address.*

YOURS TRULY
Sd/- S. N. BOSE

Einstein did not send any reply to Bose's second letter, but he had not forgotten his paper as will be seen later.

Meanwhile, early in 1924, Bose had applied to the Dacca University for a two-year leave for study abroad, but he had not received any definite reply. Fortunately, Einstein's first post-card letter gave Bose a sort of passport to study-leave. He got two years' leave on generous terms. In early September 1924, S. N. Bose sailed from Bombay aboard a steamer of the Lloyd Triestino line. After some stops for sight-seeing on the way, he arrived in Paris around mid-October 1924, and took lodgings at 17 Rue du Sommerard, Paris 5^{e}, a building which housed the Indian Students' Association. Soon after arrival in Paris, Bose addressed another letter to Einstein.

17 *Rue du Sommerard*
Paris Ve
26-10-1924

Dear Master :

My heartfelt gratitude for taking the trouble of translating the paper yourself and publishing it. I just saw it in print before I left India. I have also sent you about the middle of June a second paper entitled, "Thermal equilibrium in the Radiation Field in the presence of Matter."

I am rather anxious to know your opinion about it, as I think it to be rather important. I don't know whether it will be possible also to have this paper published in Zeit für Physik.

I have been granted leave by my university for 2 years. I have arrived just a week ago in Paris. I don't know whether it will be possible for me to work under you in Germany. I shall be glad however if you will grant me the permission to work under you, for it will mean for me the realization of a long-cherished hope.

I shall wait for your decision as well as your opinion of my second paper here in Paris.

If the second paper has not reached you by any chance, please let me know. I shall send you the copy I have with me.

With respects,

YOURS SINCERELY
Sd/- S. N. BOSE

Meanwhile, the paper referred to by Bose had been translated by Einstein and sent to *Zeitschrift für Physik,* where it was received on July 7 1924 and published in the August-September issue under the title, "Wärmgleichgewicht im Strahlungsfeld bei Anwesenheit von Materie."

Just as he had done at the end of Bose's earlier paper, Einstein added a note at the close of this paper also. He wrote:

"I hold that Bose's hypothesis regarding the probability of the elementary radiation process is not justified on the following grounds :

For the statistical equilibrium between Böhr's state with another, the relation,

$$\frac{n_r}{g_r} \quad \frac{N_\nu}{A_\nu+N_\nu} = \frac{n_s}{g_s}$$

is valid, as Bose has stated.

It follows from this that the probability for the transitions $r=s$ and $s=r$ must be proportional to the left or the right sides, of this equation. The transition probability for a molecule must therefore be as $\frac{N_\nu}{A_\nu+N_\nu}$: 1 (if we put half of the statistical weights of both states equal to 1 for simplicity). From the knowledge of thermodynamic equilibrium nothing more can be extracted. From the hypothesis introduced by me these probabilities will be proportional to N_ν (i.e., density of radiation) and $(A_\nu+ N_\nu)$ respectively, whereas from the hypothesis of Bose these will be $\frac{N_\nu}{A_\nu+N_\nu}$ and 1 respectively.

From the latter hypothesis, the external radiation can very well effect the transition of a state Z_r of lower energy to the state Z_s of higher energy, but not inversely the transition from Z_s to Z_r. But this again contradicts the validity of the well-known basic law that classical theory must represent quantum theory in the limiting case. According to the latter theory, for example, the radiation field can transmit positive as well as negative energies to a resonator (according to the phase) and indeed both are probable. The probability of both transitions must depend therefore, on the radiation-density, i.e., on N_ν, in contradiction to Bose's hypothesis. In the last edition of his book on Radiation theory, Planck has discussed in detail the question, namely to what extent, quantum theory embraces the classical theory as a limiting case.

"Secondly, according to Bose's hypothesis, a cold body must possess a capacity for absorption depending on the density of radiation (decreasing with it). In the domain where Wien's formula is valid, the bodies in cold state, must absorb 'non-Wien' type of radiation more weakly than the less intense radiation. This would have been already discovered in the case of infrared radiation of light sources, had it behaved in this way."

In his reply to Bose's letter from Paris, dated 26-10-24, Einstein wrote :

Berlin W. 30
3 *November* 1924

Dr S. Bose
17, *Rue du Sommerard*
Paris.

Dear Colleague :

Thank you sincerely for your letter of 26 *October. I am glad that I shall have the opportunity soon of making your personal acquaintance. Your papers have already appeared sometime ago. Unfortunately the reprints have been sent to me instead of you. You may have them at any time. I am not in agreement with your basic principle concerning the probability of interaction between radiation and matter, and have given the reasons in a remark which has appeared together with your paper. Your principle is not compatible with the following two conditions* :

(1) *The absorption coefficient is independent of the radiation density.*

(2) *The behaviour of a resonator in a radiation field should follow from the statistical laws as a limiting case.*

We may discuss this together in detail when you come here.

With kind regards,

YOURS
Sd/- A. EINSTEIN

Bose did not write to Einstein, in reply to the objections raised by him, for almost three months. In fact, he was sorely disappointed because his second paper, which he cherished most, did not get proper recognition from Einstein. He postponed his visit to Berlin for the time being and prolonged his stay in Paris. After deep thinking, he replied to Einstein's letter as follows :

17 *Rue du Sommerard*
Paris V_e
27*th January* 25

Revered Master :

I received your kind note of 3*rd November in which you mentioned your objections against the elementary law of probability. I have been thinking about your objections all along and so did not answer immediately. It seems to me there is a way out of this difficulty, and I have written down my ideas in the form of a paper which I send under a separate cover. It seems that the hypothesis of negative Einstrahlung stands, which as you have yourself expressed reflects the classical behaviour of a resonator in a fluctuating field. But the additional hypothesis of a spontaneous change, independent of the state of the field, seems to me not necessary. I have tried to look at the radiation field from a new standpoint and have sought to separate the propagation of quantum of energy from the propagation of electromagnetic influence. I seem to feel vaguely that some such separation is necessary if quantum theory is to be brought in line with Generalised Relativity Theory.*

The views about the radiation-field, which I have ventured to put forward, seem to be very much like to what Böhr has recently expressed in May Phil. Mag. 1924. *But it is only a guess, as I cannot say honestly to have exactly understood all he means to say, about virtual fields and virtual oscillators.*

I am rather anxious to know your opinion about it. I have shown it to Professor Langevin here and he seems to think it interesting and worth publishing.

I cannot exactly express how grateful I feel for your encouragement and the interest you have taken in my papers. Your first Post card came at a critical moment and it has more than any other made this sojourn to Europe possible for me. I am thinking of going to Berlin at the end of this Winter, where I hope to have your inestimable help and guidance.

YOURS SINCERELY
Sd/- S. N. BOSE

The aforesaid paper in which Bose had hoped to meet Einstein's objections, one which Langevin considered 'worth publishing,' was never published. No mention of it was made afterwards.

In the context of Einstein's critical comments on Bose's second paper, Sudarshan (1974) has made the following remarks : "This questione concerns the equilibrium of radiation when it is in interaction with matter and being continually emitted and absorbed. In 1915, for the special model of a Böhr atom coupled to radiation, Einstein (1917) had shown that we could get Planck's distribution provided the emission rate contained one term proportional to the number of photons in the phase cell times the spontaneous transition rate. This additional term is called stimulated or induced emission. This special model was extended to many-level systems by Einstein and Ehrenfest (1923). Pauli (1923) on the other hand, had studied the scattering of light by electrons and showed that if Compton effect was taken into account, the Planck distribution was steady. Bose (1924) proposed to take up the general case and showed that in his formulation, both the Pauli processes and the Einstein-Ehrenfest processes were included as special cases.

"This by itself should have met with general acceptance and acclaim. But Bose did point out that instead of Einstein's assumption of a stimulated and spontaneous transition rate for absorption, it is possible to consider only the spontaneous transition rate for emission provided the absorption rate is taken to be not proportioned to the number of quanta per phase cell but this number divided by this number plus one. Now as far as radiative equilibrium is concerned, this 'ansatz' is as good as the Einstein (1940) 'ansatz', since only these ratios do come in. So it would have been quite possible for Einstein to add such a foot-note to Bose's paper and call attention to the positive features of Bose's formulation. But he chose otherwise. Three years later, Dirac (1927) constructed his theory of emission and absorption of radiation and the Einstein 'ansatz' of stimulated and spontaneous emissions was seen to be a natural consequence of the matrix elements of creation and destruction operators. But then Bose did not write on radiation theory ever again."

Stay in Paris (1924–25)

Recalling the days, he had spent in Paris, Bose said to Mehra (1975) :

"I wanted to go abroad directly to Berlin but I didn't venture to go straight on, because I was not sure of my knowledge of German. I came out thinking that perhaps after a few weeks in Paris I should be able to go to Berlin to see Einstein. However, two things happened :

(*i*) Friends;

(*ii*) Letter of introduction to Langevin.

My friends who received me on arrival there, took me to their boarding house, where they were staying. Then they all insisted that I should stay there. Wel., I found it convenient to be among friends."

He was then introduced to Professor Sylvain Levi, the famous French Indologist by his friend, Prabodh Chandra Bagchi. Levi gave him a letter of introduction to Paul Langevin, Professor titulaire at the College de France.

As a teacher of Physics, Bose had been asked to familiarise himself with modern developments in the fields of both theoretical and experimental Physics. Bose's instinctive motivation goaded him to learn about experimental techniques—Radioactivity from Madame Curie and also something of X-ray spectroscopy from Maurice de Broglie. Langevin suggested that he should pursue the possibility of working in Madame Curie's laboratory,' perhaps with Mme Curie herself.' Langevin gave a note of introduction to her and Bose accordingly sought an interview. During their meeting, she carried on the conversation in English. Mme Curie believed that it was essential to know the language of a country really well in order to be able to participate effectively in its scientific and cultural life. Bose told her that he would remain in Paris for about six months and learn French well, but due to his inherent shyness, he wasn't able to tell her that he knew sufficient French already to enable him to work in her Laboratory. She preferred to have her own ideas and told Bose to be around for a longer time, not hurry but concentrate on the language. Thus Bose's desire for learning experimental techniques in Radioactivity under Mme Curie's guidance remained unfulfilled.

Since Bose had showed an interest in X-ray spectroscopy, Langevin gave him an introductory letter to Maurice de Broglie also. The latter apparently knew of Bose's theoretical work; and he readily allowed Bose to work with his chief assistant, Alexandre Dauvillier. There he learnt diverse techniques of X-ray crystallography. He also became deeply interested in theoretical aspects of crystal behaviour. These experiences stood him in goodstead when he had the opportunity to help K. S. Krishnan and his group of students, during their investigations on crystal magnetism at the Dacca University.

Sojourn to Berlin

After about a year's stay in Paris, Bose went to Berlin, and wrote to Einstein on October 8, 1925, seeking an appointment to meet him. Einstein was then on his annual visit to Leyden. The long-cherished meeting with him materialised several weeks later, when Einstein returned to Berlin. Meanwhile Einstein had already published three papers utilising Bose-statistics. His last decisive contribution to statistical thermodynamics had been published in January that year. He had now moved on to other things including the beginning of his search for a unified field theory. And so, Bose lost the chance of a life-time for a fruitful collaboration with Einstein. Nevertheless, their meeting was most interesting. Einstein wanted to know how he had hit upon the idea of deriving Planck's law in this particular way ! He also wanted to know whether Bose's kind of statistics did really mean something novel abut the interaction of quanta and whether Bose could work out its details. Bose hesitated because the duration of his study leave was limited and he was anxious to widen the range of his scientific knowledge during this brief period. And so,

Einstein gave him a letter of introduction, which enabled him to attend the Physics colloquium and to borrow books from the university library. It also gave him the privilege of meeting and forging personal friendship with top-ranking German Scientists like Fritz Haber, Otto Hahn, Lise Meitner, Walther Bothe, Michael Polanyi, Von Laue, Walter Gordon, Eugene Wigner and others. He actively engaged himself in X-ray crystallography at Polanyi's laboratory, and in theoretical studies with Gordon (of Klein-Gordon equation fame). He visited the 'Radioactivity' laboratory of Hahn and Meitner quite often. Meanwhile Heisenberg's (1925) paper on quantum mechanics came out and Einstein became very excited about it. He wanted Bose to try to see what the statistics of light quanta and the transition probabilities of radiation would look like. Bose discussed the problem with Gordon and tried to understand the trend of the new theory. Meanwhile Einstein lost his interest in the problem, because he refused to believe that it was by any means the final theory. During this interlude, Bose held fruitful discussions with Einstein on Relativity theory, Unified field theory and Hilbert's (1924) theory.

Later, during the summer of 1926, Bose visited Göttingen and met Max Born and Erich Hückel. Thus Bose's first European visit was very profitable to him although he did not publish any scientific paper during this period. He returned to Dacca in 1926.

At Dacca (1926–44)

Before his return to Dacca, his friends had advised him to apply for a Professorship of Physics at Dacca University. Since he did not possess any doctorate degree, they suggested that he should obtain a letter of recommendation from Einstein. Einstein was surprised at the request because he thought that Bose's scientific work should entitle him to the position. Einstein's recommendation notwithstanding, the professorship at Dacca was offered to Dr D. M. Bose, who declined. S. N. Bose was then appointed Professor of Physics and Head of the Department in 1927.

This was the beginning of the second phase of his professional career which extended from 1926 to 1944 and was spent at Dacca University. He had just returned to a medieval university after a fairly long visit to some modern European universities and laboratories. And so, he strove to see how science could do more and more for his countrymen. The accent was not on the problem of science, but what science could do for the common man. He had embarked on a professional career during the sealing wax and string era. His conviction was that it was necessary to build one's own appratus in order to understand its performance fully. Equally competent as both a theoretician and an experimentalist, Bose would take nothing for granted with respect to mathematical formulations or laboratory procedures. Just as he insisted upon deriving mathematical equations himself, rather than relying upon the literature (indeed he disdained to "look things up"), he likewise insisted upon designing his own experimental equipment. Returning to Dacca, he launched a drive into experimental physics. He designed and constructed X-ray diffraction cameras for rotation and powder photography. When great interest developed later in the study of extra Laue reflections, known as thermal diffuse scattering, he designed a sensitive Bragg-type X-ray spectrometer. He also formulated an easy method for identifying the indices of the plane of reflection of Laue photographs recorded in a cylindrical

camera. Under his leadership, studies in crystal structure were undertaken perhaps for the first time in India. It was also his quest to assemble around him an active, gifted and perceptive band of colleagues like K. S. Krishnan, S. R. Khastgir, K. Banerjee and others. He did not care to build up any school of experimental research of his own; rather, in his characteristic way, he tried with the limited resources of his department, to provide facilities for research to all his colleagues in their respective fields of specialisation.

He had a fascination for chemistry as well. Perhaps he imbibed it from Professor Herman Mark, whom he used to visit quite often in Berlin. At Dacca, he made a personal cell for research in organic chemistry. Assisted by P. K. Dutta, he studied the reactions of *p*-acetyl-amino-benzene-sulphonazide and *p*-toluene-sulphonazide with pyridine. He also worked on the synthesis of some *r*-pyrone derivatives related to Patulin, which is equally bacteriostatic to both gram-positive and gram-negative organisms. It has also a beneficial effect on the treatment of common cold.

When his experimental laboratories began running in full swing, Bose returned to Theoretical Physics, after about a decade.

In 1936–37, Bose published two papers on D^2-statistics, to which his attention had been drawn by Professor P. C. Mahalanobis, Founder-Director of Indian Statistical Institute. In these two papers, he found out recurrence, algebraic relations and differential equations, satisfied by the moments of this distribution. Both these papers exhibit his great skill in mathematical manipulation.

In 1938, he investigated the problem of total reflection of radio-waves in the ionosphere, by solving the classical Lorentz equation by the method of characteristics. From this general scheme, four different possible conditions for the total reflection of radio-waves can be obtained only under different sets of simplifying assumptions. It is said that he was drawn to the problem at the inducement of Professor M. N. Saha, during his lecture at the Dacca University.

In 1939, he published a paper on Lorentz group. In this paper, a four-dimensional transformation was decomposed into two factors which lead to the spinors from algebraic considerations.

In 1941 (jointly with S. C. Kar), he published a paper entitled—"The complete solution of the equation

$$\nabla^2 \phi - \frac{\partial^2 \phi}{c^2 \partial t^2} = -4\pi\rho\,(x, y, z, t).$$"

Incidentally, a similar equation had been used rather empirically by H. J. Bhabha during the course of a lecture on cosmic rays at the Department of Mathematics, Calcutta University.

In 1943 (jointly with K. M. Bose), he published "A note on Dirac equations and the Zeeman effect." Here, the exact solution of the Dirac equation for hydrogenic atom in a magnetic field was obtained in terms of some polynomials.

In 1945, Bose deduced the integral equation in the momentum space for Schrödinger's wave-equation for the Hydrogen atom and discussed the physical problem from the integral equation.

It was no wonder Bose could manage to utilise his giant intellect successfully in so many diverse fields ! As a matter of fact, he was very sensitive, contemplative and

retiring by nature. He always "needed someone to provoke him with some challenging problem in physics or mathematics." Once aroused, he could work ceaselessly on till the goal was achieved.

Bose lived in Dacca for about a quarter of a century. He was loved and respected by his colleagues and students alike. The general public of Dacca were also proud of him. But the political atmosphere of Dacca cast a shadow over the academic environment. The communal tension lurked beneath the festive board, which disturbed S. N. Bose intensely. At this moment, a vacancy of Khaira Professorship occurred at the Calcutta University, due to the sudden death of its previous incumbent Professor B. B. Roy. Professor S. N. Bose accepted the offer and left Dacca for good.

Back to Calcutta (1945–56)

Bose began the third phase of his professional career at the Calcutta University. During this period, he found a new way of work. He did not work in solitude as an individual, he worked in collaboration with others. When he was appointed Head of the Department of Physics and Dean of the Faculty of Science, he spread his wings over most of the departments of science. He accepted Böhr's aphorism : "*The main human lesson drawn from investigation of natural phenomena ever more remote from ordinary experience is the recognition of the inseparability of objective knowledge from our ability to put questions to nature by means of experiments suited to give unambiguous answers.*" And so, this incredibly versatile man delved deeply into the ocean of knowledge and attempted to familiarise himself with its unknown facets. A number of young, keen and serious research workers congregated around him and started colloquia on advanced topics of physics and mathematics. Once his interest in a challenging problem was aroused: he would not rest until it was solved. If somebody approached him with an original paper, he would first try to understand the motivation and main objective of the paper and what the author wanted to arrive at. Next he would formulate the paper in his own way with pencil and paper, and finally, would solve the problem. Quite a number of times, his methods and his results were much more general than those envisaged in the paper. "Always read the Masters," he would say—"These are people who made really significant contributions to the subject. Lesser authors cleverly bypass the difficult points."

After attending a seminar, and listening to the discussions on various aspects of Einstein's Unified Field Theory, Bose was drawn into its vortex, when he came to learn about the inability of experts to find exact solutions of the field equations. In the geometrical aspect of the theory, it is necessary to solve sixty-four equations with affine connections and the metric tensors and their derivatives. Professor Bose plunged into the problem with single-minded devotion and succeeded in finding an exact solution. The importance of Bose's work will be evident from the following remarks of Schrödinger : "In the general case, it is next to impossible to produce it in a serveable tensorial form. This is hard to believe, unless one tries." During 1953–55, Bose published five important papers related to Unified Field theory. These are believed to be a mathematical *tour de force,* even though they did not create as great a stir as his earlier ones of 1924. The solutions of the equations for the

general case are given in the first two papers. In others, the complete development of the physical theory and relevant mathematical results are given. He sent these papers to Einstein, who wrote that he did not quite follow how precisely Bose's solution was to be used in physics and discussed it in detail in one of his own papers.

Bose wrote down his reply at length and wanted to meet Einstein personally at Bern, on the occasion of the celebration of the 50th anniversary of the discovery of the theory of relativity. Unfortunately fate intervened, and when the news of the death of his master came, Bose was so overwhelmed with grief that he tore and threw away the only copy of his important paper.

It is a paradox of Bose's career, that he made only two outstanding contributions to mathematical physics—the one on "Statistics," in the twenties and the other on "Unified Field Theory" during fifties with a gap of about thirty years between the two. The answer is that Bose was a rare combination of kaleidoscopic versatility and evergreen vitality which had made him fill the intervening gap of thirty years with studies of subjects as diverse as Experimental Physics, Chemistry, Mineralogy, Biology, Soil Sciences and Archaeology.

Since his predecessor in Khaira Laboratory happened to be an X-ray spectroscopist, Professor Bose guided his students in their original lines. An important project comprised the study of thermoluminescence. The rapid scanning spectrophotometer designed and fabricated under his guidance is a typical example of his interests and abilities in instrumentation work. In 1954, at the Crystallographic Conference in Paris, Bose presented the constructional details of his spectrophotometer, which was subsequently adopted in some well-known laboratories in Europe. He also encouraged the present writer to install the first indigenous Radio-carbon dating equipment in India in 1953. He sponsored measurement of radioactivity in thermal springs, which had far-reaching effects in balneology and balneotherapy. Indeed the renovation of Bakreswar thermal springs for the purpose of building a spa-sanatorium is mainly due to his initiative at the instance of the late Dr B. C. Roy. An extensive study of Indian clay minerals by X-rays, chemical analysis and cation exchange technique was also undertaken by his research scholars.

In the realm of Organic chemistry, he embarked on a laborious routine involving synthesis of Emetine and Quinine, but he was forestalled by foreign workers. Considering the importance of Germanium as a strategic material in electronic industry, he made a systematic search for Germanium in the sulphide minerals of India. In collaboration with his class-fellow, Professor P. B. Sarkar, of the Department of Inorganic Chemistry, he actually extracted Germanium from a sample of Sphalerite from Nepal.

From 1951, Bose had been visiting Europe almost every year. He visited Germany in 1951 and met Professor Walther Bothe, Otto Haxel, J. H. D Jenson and H. Maier-Leibnitz in Heidelberg. He also visited Göttingen to meet Professors Otto Hahn, Werner Heisenberg and Houtermans. In 1953, he was asked to attend the World Congress for General Disarmament and Peace at Budapest, Hungary. Invitations also came from Soviet Russia, Denmark and Czechoslovakia. Bose took this opportunity to visit Geneva, Paris, Copenhagen, Zürich and Prague. He met Professor Pauli in Zürich and Niels Böhr in Copenhagen.

Bose's next trip was to England in 1956 to attend the meeting of the British Association for the Cultivation of Science. Two years later he was back in London to attend the Royal Society meeting where he was elected a Fellow. In 1962, he went to Sweden and from there to Moscow to attend the Peace Conference. In August 1962, he was invited to Japan to attend a Seminar on Science and Philosophy.

In 1956, at the age of 62, Bose retired from the Calcutta University and became the Vice-Chancellor of Visvabharati.

Bose at Santiniketan (1956–58)

Bose lost no time in getting down to work. He drew up a Master Plan for re-organising the set-up at Visvabharati by introducing science courses. He wished to create facilities for advanced training and research in some familiar branches of science. It is a pity that his motive was misunderstood and some old-timers of Santiniketan thought that this move would go against the age-old tradition of Santiniketan. They opposed him vehemently. Thus ended the tragic episode about his efforts to upgrade the Science curriculum at Santiniketan. Actually, his affinity and good relations with Rabindranath Tagore were eminently suitable to launch such a drive. Incidentally, Tagore had dedicated his book entitled "*Visva-Parichay*" (Introduction to the World of Science) to Satyendra Nath Bose. However, his brief interlude at Visvabharati was soon over and Bose returned to Calcutta to the great delight of his students, friends and admirers.

Bestowal of Honours

He had all along been averse to publicity and self-aggrandizement. He remained satisfied with a mere M.Sc. degree appended to his name. Indeed, he had resolved to espouse obscurity as much as St. Francis of Assisi had espoused poverty. But towards the end of his career, honours and recognitions were showered upon him in abundance. These included the following :—

(1) Foundation fellowship of the Indian National Science Academy (1935).
(2) D.Sc. (*h.c.*), Calcutta University (1957).
(3) D.Sc. (*h.c.*), Jadavpur University (1957).
(4) D.Sc. (*h.c.*), Allahabad University (1957).
(5) F.R.S., Royal Society, London (1958).
(6) Deshikottama, Visvabharati University (1961).
(7) D.Sc. (*h.c.*) Indian Statistical Institute (1963).
(8) D.Sc. (*h.c.*) Delhi University (1964).

Among the many distinguished positions and offices he held were :—

(1) Sectional President, Physics and Mathematics at the Madras Session of the Indian Science Congress (1929).
(2) President, Indian Physical Society (1945–48).
(3) General President, Indian Science Congress, 31st Session at New Delhi (1944).
(4) President, National Institute of Sciences of India (1949–50).
(5) Member of the Rajya Sabha, Indian Parliament (1952–58).

National Professorship (1958–74)

We now reach the final phase of his professional career. It occupied three five-year terms as National Professor extending from 1958 till his death. He started in a new style, of a very special character, acting and talking as an equal in a group of young and enthusiastic scholars undergoing training in diverse branches of science. Tempered by the years, with his luxuriant crop of white hair, he came to be regarded as a sort of father confessor, giving counsel on any problem on which any one sought his guidance. To him may be applied what Francis Bacon said about himself, "*I have taken all knowledge to be my province.*"

His fortê was a profound and clear understanding of the fundamentals of sciences. However, he had now come to the conclusion that time had changed the basic character of physics. It had become a large enterprise extending beyond the ivory tower of the Universities and research Institutions. He scanned the horizon and set his intellectual eye on the workings of Nature. He persuaded the present writer to join him in an exploration of Helium, an ingredient for loss-free electrical power transmission of the future. Earlier, an indication of the presence of this gas in fair amount was detected as an important constituent of the natural gas emanating from Bakreswar thermal springs in West Bengal. Now he supervised the construction of a field laboratory at the site. The enthusiasm and ideas of other people would not have been enough, however, if a man of his stature had not supported it, and worked out every detail. After his demise, the project was taken over by the Department of Atomic Energy, Government of India.

Fine Arts and Music

His personality cast its spell of genius on the common people. They regarded him as a living myth or legend. Often in informal musical concerts, Bose, the connoisseur of classical music, would close his eyes and seem to fall asleep, to everybody's dismay. But at the end, he would open his eyes and put extremely pertinent questions to the performer. He was extremely fond of instrumental music and played on the "*Esraj*" like a master. People have seen him playing on his "*Esraj*" in a lonely corner of his home, with tears rolling down his eyes.

He also had an absorbing interest in fine arts, and would often discuss about the elegance of mural paintings with maestros like Jamini Roy. Seldom did he decline to attend any musical soiree, cultural function or art exhibition, when invited.

Reminiscences

The conscious and the unconscious appeared to have a strange deep unity in his restless brain. At different levels of perception the legend carved out a superb figure of a giant who was engagingly childlike and a man of supreme genius who was entirely human. Often he appeared to be immersed in laziness, but the somnolescence was full of alertness. Once presiding over a lecture of Professor Niels Böhr at the Saha Institute of Nuclear Physics, he had closed his tired eyes and it seemed that he was asleep. But when Professor Böhr hesitated before the black-board and said "Perhaps Professor Bose can help me here," he at once opened his

eyes, explained the mathematical point and seemed to revert to his unseeing meditation. On another occasion, at the same venue, he was presiding over a lecture by Professor Frederic Joliot-Curie. After introducing the speaker in English, he closed his eyes as usual. But when Professor Joliot asked for an interpreter to render his speech in French into English and none came forward, Professor Bose opened his eyes, stood up and translated Professor Joliot's speech into chaste English, sentence by sentence.

The most attractive feature in Professor Bose's outlook was the blend therein of the orient and occident. He combined in himself the temper of the visionary and that of the man of the world. He had witnessed life in its manifold phases—its brilliant sunshine, its weeping gloom. He had suffered and endured the buffets of life, staggered for a moment and then went on his way oblivious of the past and heedless of the future. Naught but a truly religious spirit could have given him the inward joy and sweet content which enabled him to laugh at the world's waywardness to scorn. His greatest conquest was the conquest of self.

His life resolved itself into a kind of perpetual giving. He was a tower of strength to his companions. His enduring love and sympathy lifted their spirits and cut paths through their sickness, loneliness, disappointment and despair. He awakened their awareness, strengthened their faith, deepened their love and steeled their courage to face life's grimmest challenges without fear. He had the free immolation of a being that could give all and receive nothing and above all the quality of a soul in which neither fame nor adversity could change the exceptional purity. He did know how to be famous. He had a life-long aversion for the lime-light. Natural kindness, strong nationalism, extraordinary intelligence and graceful sensitivity were the keynotes of his greatness.

Last Days

On the occasion of the attainment of his eightieth year on January 1, 1974, the Calcutta University arranged for an international seminar. It was specifically meant to celebrate the golden jubilee of "Bose Statistics." The invitations were sent clear around the world. The great and the learned accepted. This meeting was to be a gathering of brains, a survey of the world's opinion on the impact of "Bose Statistics" on contemporary science. The men of science congregated from all parts of the world. The inaugural meeting was held in the lecture theatre of Bose Institute on January 8, 1974. The panel of speakers carried dazzling names. But they were all dwarfed by a man with his luxuriant crop of white hair as his trademark—Professor Satyendra Nath Bose. He tried to pull himself up from his seat. He was requested to speak while sitting. As he delivered his impromptu address, lights flashed and cine-cameras around, but the message and the genius and the role of his prose were there. He naively recounted nostalgic reminiscences of bygone days and speculated on the possible influence of heavenly planets, which had guided him to write a four page paper fifty years ago, and which had now acted as a spark to bring together so many distinguished scientists from the East and the West. He concluded prophetically with the following words : "*Well, after all, if one has lived through so many years of struggle, and if at the end he finds that his work has been appreciated, he feels that he does not need to live long. I think this is the faithful end to a long career.*"

During the following weeks, he carried himself through a hectic programme—attending seminars, inaugurating exhibitions, lecturing at social functions, all held in his honour. Perhaps the responsibility of excuting so many diverse programmes was too big and widespread for a man of his age to carry. He took on too much and exerted himself beyond the limits of his endurance. Worn out by his ceaseless activities, he was unable to withstand an attack of bronchial pneumonia that followed recurrent attacks of respiratory troubles. Knowing more about his disease than his attending physician, he realised it how it would end for him and faced death severely during morning hours of February 4, 1974. His mortal frame was consigned to flames at Keoratala Crematorium in the presence of his close relatives, friends, co-workers and students, who loved and respected him.

With Professor Satyen Bose's death an era ended—an era of great men who created Science in India. We are perhaps too close to him to judge his great, ness. Only from a distance can one see how much Mount Everest towers over the other peaks of the Himalayas. It was Bose himself who helped to create the continuation of his spirit into the future. It puts us under obligation to continue what he wanted to do.

S. D. CHATTERJEE

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SOHAN LAL TANDON

(1922–1975)

Elected F.N.A. 1974

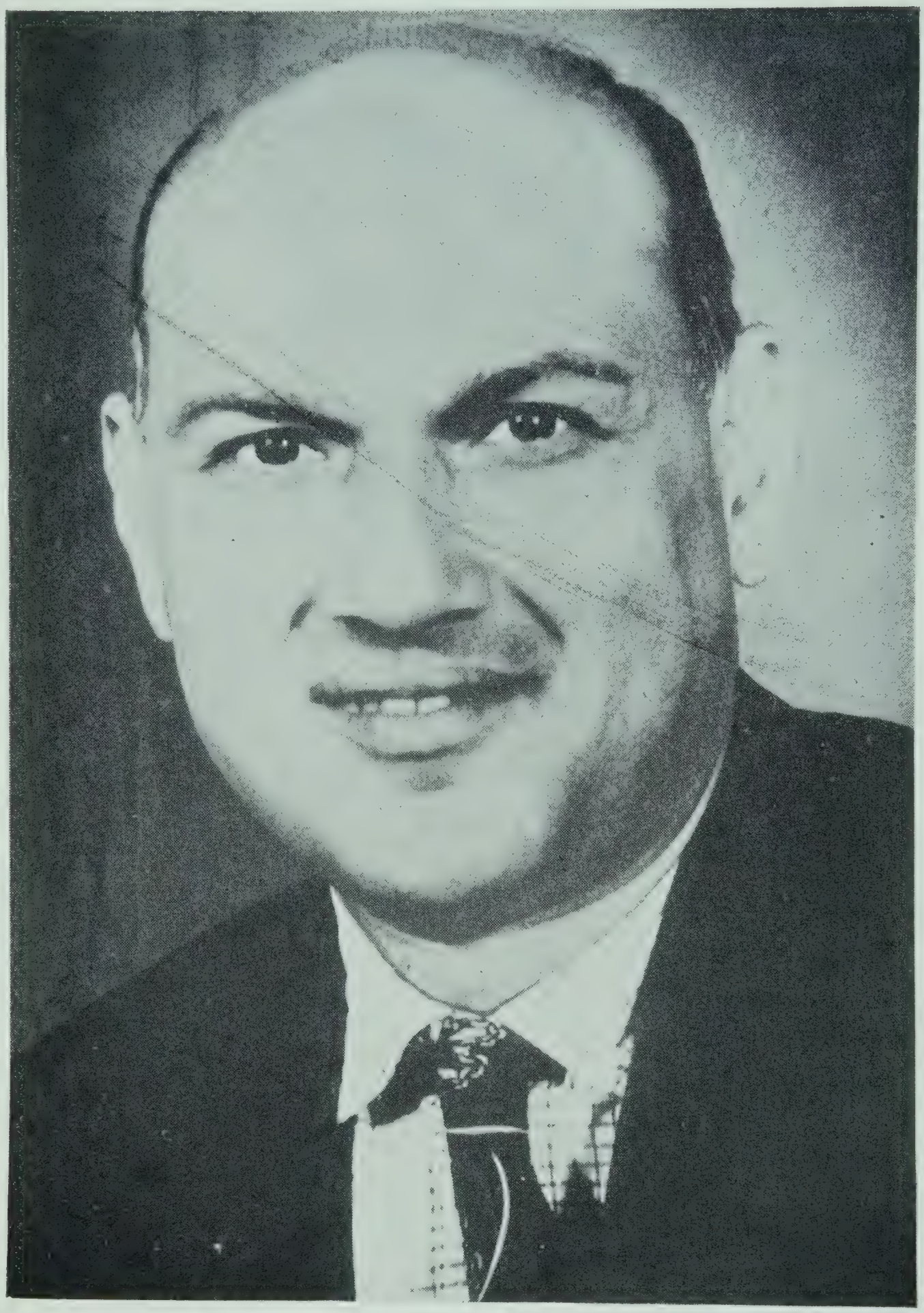
SOHAN LAL TANDON was born on August 11, 1922 in Nowshera, a village in North West Frontier Provinces (now in Pakistan) and died of a massive heart attack in Delhi on March 27, 1975. Being the eldest of six brothers and two sisters, Sohan Lal was greatly influenced by the life and style of his father, late Shri Piara Lal Tandon who retired as the Senior Marketing Officer in the Agricultural and Marketing Directorate of the Government of India.

EDUCATION

Sohan Lal had his primary and secondary education at Agra, Lucknow and Delhi. After the High School Examination of the Delhi Board of Secondary Education in 1938, he joined the medical (Botany, Zoology, Chemistry, etc.) group at Hindu College (a constituent college of the University of Delhi) from where he passed the Intermediate Examination in 1940. He then joined the Banaras Hindu University from where he graduated in 1943 with Chemistry, Botany and Geology, and later obtained his Master of Science degree in Agricultural Botany in 1945. While he was doing M.Sc., he was awarded the University Merit Scholarship. Love for Agricultural Botany brought young Sohan Lal back to Delhi where he joined the Post-Graduate Diploma Course in Genetics and Plant Breeding at the Indian Agricultural Research Institute (IARI) and obtained the Associateship in 1947. During these two years at IARI, he was greatly influenced by Dr B. P. Pal, who initiated him into Genetics and Plant Breeding. Soon after obtaining the Post-Graduate Diploma, Sohan Lal joined the newly established Department of Botany at the University of Delhi as a Research Assistant in 1947 and was later appointed as Lecturer in 1948. Thirst for knowledge and a *Watumall Scholarship* took him to the Washington State University, Pullman, U.S.A. in 1950, where he took his Doctorate in 1952. The thesis was entitled, "Cytogenetics of *Oenothera* affinis-mollissima complex." During this period he worked under the able guidance of Professor Adolph Hecht—a well-known authority on the evening primrose.

CONTRIBUTIONS TO SCIENTIFIC KNOWLEDGE

After his return to the Delhi University in 1953, he devoted himself to establish a strong school of cytogenetics, as there were only a very few Indian Universities



Eltandon

offering Cytogenetics at that time. He published over ninety research papers dealing with the cytotaxonomy of a number of angiospermic taxa, the role of polyploidy in evolution with special reference to the solanums, the mechnnisms of evolution of higher chromosomal forms based on their genomic analysis, the cytoembryology of the endosperm and induced polyploidy in relation to floriculture. Thus, he greatly enriched cytogenetics with his notable and outstanding contributions. Each one of the above areas bears ample evidence of his dedication to research, dexterity of technique, meticulous observation and critical assessment.

With B. M. Kapoor (a research student, presently Associate Professor, University of Nova Scotia, Halifax, Canada), he worked out the cytology of endosperm of a number of taxa belonging to the families Amaryllidaceae, Liliaceae, Papilionaceae, Compositae, Ranunculaceae, and Solanaceae. On the basis of these studies, he concluded that low seed-setting in some of the taxa investigated was due to the failure of endosperm, leading to embryo abortion. Endosperm breakdown is caused primarily by the cumulative effect of the mitotic abnormalities which appear in the form of bridges, laggards, dicentric chromosomes, and fragments. High degree of polyploidy, aneuploidy, and amitosis was characteristics of the degenerating endosperm. These findings have subsequently been corroborated by a number of workers.

His work on *Solanum nigrum* revealing the evolutionary origin of the hexaploid form has been widely recognised. In collaboration with G. R. Rao (a research student, presently Reader in Botany at the Aligarh Muslim University), he was able to establish experimentally that the hexaploid solanums have arisen as a result of natural hybridisation between a tetraploid and a diploid cytotype. The genetic constitutions of these forms have been discovered to be AA (diploid), BBCC (tetraploid) and AABBCC (hexaploid). These findings are presented in a chapter of the book, *Evolutionary Studies in World Crops : Diversity and Change in the Indian Sub-continent*, edited by Professor Sir Joseph Hutchinson, F.R.S. Cambridge University Press, England.

Honours

In recognition of his research contributions, he was promoted to Readership in 1958 and Professorship in 1972. He was elected a Fellow of the Indian National Science Academy in 1974. He took all the honours in his stride with equanimity. He was Founder Member of the Society of Cytologists and Geneticists and a member of the Indian Society of Genetics and Plant Breeding. He served the latter as a Vice-President in 1967.

A Dedicated Researcher

In spite of his academic pre-occupations, Professor Tandon lent his services to various National Committees of University Grants Commission, Indian Council of Agricultural Research, Council of Scientific and Industrial Research, Indian National Science Academy, Board of Secondary Education, Governing Bodies of a number of Colleges and Institutions of the University of Delhi, and boards of studies of a

number of Universities. In fact, his mastery, promptness and thoroughness in matters both academic and administrative were examplary. This is reflected in his research papers as well as in his popular scientific articles and publications on organisation of teaching and research in Biological Sciences. Being a good sportsman in his student days, his personality had a stamp of true sportsmanship. His balanced perception and catholicity of views endeared him with all his colleagues and friends.

With his pioneering zeal and untiring effort, he trained an energetic band of research workers who now occupy important academic positions in India and abroad. Sohan Lal was an inspiring teacher and helped the University of Delhi in organising many academic programmes.

He is survived by his wife Pushpa, two sons and one daughter and, indeed, an echelon of colleagues, a large band of students, many friends and a multitude of admirers. His brief, but dedicated service to science and society will long be remembered, not only by his contemporaries, but also by posterity.

UMAKANT SINHA

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DEBENDRA MOHAN BOSE

(1885-1975)

Foundation Fellow 1935

Birth, Parentage and Childhood

Debendra Mohan Bose was born in Calcutta on November 26, 1885. His ancestral home was Joyshidhi in the District of Mymensingh, now in Bangladesh.

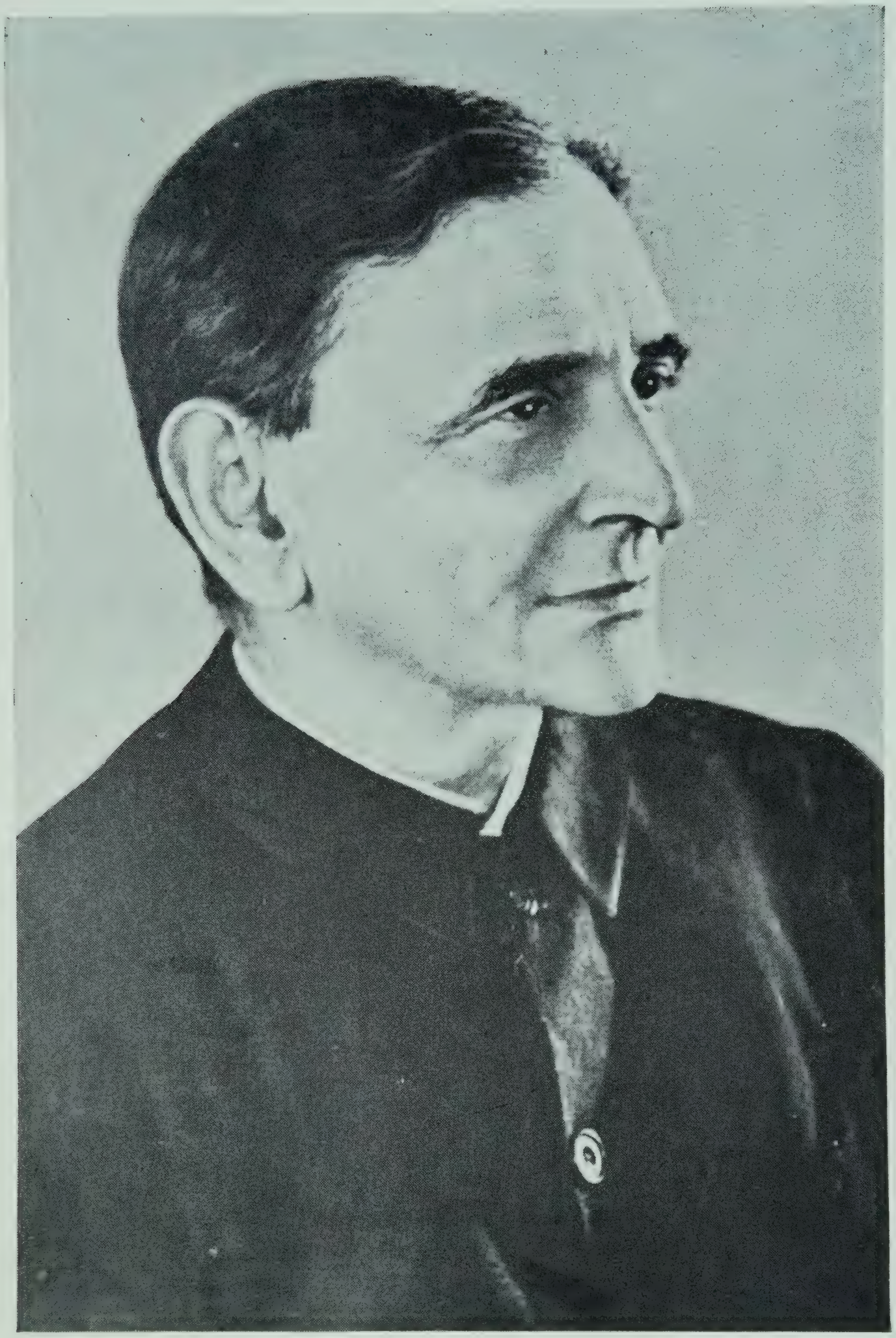
His father, Mohini Mohan Bose, was probably one of the first Indians to have visited the United States of America. He studied Homoeopathy there, and, on his return, set up practice as a physician and also as a teacher of this branch of medicine. His uncle, Anand Mohan Bose, was the first Indian Wrangler in Mathematical Tripos from Cambridge. Though he was called to the bar, Ananda Mohan spent his life in religious, educational and political pursuits. He was one of the pioneers who brought about the renaissance of modern Bengal. His contribution to the service of his Motherland was duly recognised when he was elevated to the Presidentship of the Indian National Congress in 1898.

Debendra Mohan's mother was Srimati Subarnaprabha Bose, younger sister of Sir Jagadish Chandra Bose. She was a remarkable lady, who devoted most of her later years, after her own sons were grown up, in looking after the education and welfare of orphans, children of relatives and friends, who lived in distant lands. Many sought refuge in her home.

Since 1870, the families of the forefathers of Debendra Mohan Bose had started migrating from the Districts of Mymensingh and Vikrampur (Dacca) in East Bengal to Calcutta. They took up residence around Sealdah railway station, encompassing a semi-circular area of about 2 sq. miles, which comprised portions of Lower and Upper Circular Roads, Dharmatalla Street, Bowbazar and Mechuabazar Streets. Debendra Mohan's father and maternal uncle, Jagadish Chandra Bose, spent their youths in this locality, which was bordered by residences of Babu Keshab Chandra Sen on the South, Pandit Iswar Chandra Vidyasagar on the West and Raja Rammohun Roy on the North. During his childhood, Bose closely watched the growth and development of educational, social, scientific and industrial organisations in this area. He also became acquainted with some of the pioneers, who ushered in the dawn of Indian renaissance.

Formative Influence on the Young Scientist

Before 1898, Acharya Jagadish Chandra used to live with Debendra Mohan's father in the latter's family house at 64/1, Mechuabazar Street. It was to this house again, that Acharya Prafulla Chandra Rây came on his return from Edinburgh, to live with



D. M. Baker

his friend. The house was situated on a level, lower than the surrounding plots of land. This meant that whenever there was a heavy shower, the place was flooded. Rafts would be made, boats would be borrowed and young Debendra Mohan and his companions had great fun. In 1901, the family shifted to its home at 92/3, Upper Circular Road.

Those were the days of great hopes and aspirations. Many national projects were in the offing. Prafulla Chandra Rây, who had then shifted to 91, Upper Circular Road had founded the Bengal Chemical and Pharmaceutical Works. Pandit Sivanath Sastri and Nil Ratan Sircar were frequent visitors. Here, and later to 93, Upper Circular Road, also came Rabindranath Tagore, Loken Palit, Sarala Debi, Charuchandra Dutta ad Sister Nivedita—great names in the cultural and educational history of Bengal. There were other inspiring figures too. The renowned Swedish scholar, M. Hammergren, came all the way from his native land to gather materials about Raja Rammohun Roy and the Brahmo Samaj. It was he who interested young Debendra Mohan in European Masters like Goethe, Schiller and Ibsen. In later years, Dr D. M. Bose often used to recall with much amusement, Hammergren's astounding ability to imbibe cod-liver oil (that horror of children) without the slightest facial contortion.

Debendra Mohan's father died early in 1901 and Acharya Jagadish Chandra was childless. And so, he came under the tutelage of his illustrious maternal uncle from his early boyhood and was constantly helped and guided by him. Poet Rabindranath Tagore also played a major role in shaping young Bose's destiny.

School and University Education : Preliminary

Debendra Mohan's early education started at the Brahmo Girls' school, then located at 13, Cornwallis Street, Calcutta. Next, he sought admission into the City School and passed the Entrance examination with distinction. After matriculating, he joined Presidency College and passed the F.A. examination in 1902. During his boyhood, it was tacitly assumed that Debendra Mohan would undergo training in Science in order to enable him to carry on Jagadish Chandra's pioneering researches, but fate intervened. After Debendra Mohan's father's death in 1901, Jagadish Chandra became his sole guardian. It was now necessary, under the changed circumstances, for his nephew to enter into a profession to support his family. He suggested that Debendra Mohan should join the Bengal Engineering College at Sibpur. Accordingly, he got himself admitted to the College and studied for one year at the Institution. Unfortunately, he went down with a severe attack of fever and abandoned the idea of returning to the malaria-infested place again. Poona was considered as an alternative and since knowledge of Geology was essential for engineers, he got himself admitted into the third year B.Sc. class of Presidency College in 1903, with Physics as his main and Geology as one of his subsidiary subjects. He passed the B.Sc. examination with honours in 1905 and the M.A. examination in Physics in 1906 standing first in the Calcutta University. For a year, he worked as a research scholar under his uncle, and obtained his initiation into Sir J. C. Bose's investigations in plant physiology.

In 1907, Bose went to England and was admitted as an advanced student in Christ's College, Cambridge. He worked for sometime in the Cavendish Laboratory

under the guidance of Sir J. J. Thomson. Here, he had the rare opportunity of observing C. T. R. Wilson in his cloud-chamber experiments of photographing the tracks of ionizing particles and radiations. In 1910, he joined the Royal College of Science, London, where he obtained in 1912, the A.R.C.S. diploma, as well as B.Sc. in Physics with a first class.

Returning to Calcutta, he joined the City College as Professor of Physics in 1913. In April 1914, he was appointed Sir Rash Behari Ghosh Professor of Physics at the Calcutta University. Soon after, he was awarded Ghosh Travelling Fellowship for two year's advanced study in Physics. He went to Berlin University and was assigned to Professor E. Regener, whose accurate determination of the elementary charge had then attracted considerable attention. Unfortunately, the first World War broke out and Bose was interned in Germany for sometime. However, he was permitted to continue his studies under Professor Regener and was assigned the problem of constructing a new type of cloud chamber for further study of the tracks of ionizing alpha and beta particles. His earlier training under C. T. R. Wilson proved useful and soon he designed a modified Wilson type cloud chamber to photograph the tracks of recoil protons produced during the passage of fast alpha particles through a hydrogen filled chamber. The results were interesting. He was able to verify Darwin's formula for collision between fast moving charged particles and molecules. He carried out further studies on recoil of delta particles, whose discovery had just been announced by Bumstead. However, he was not permitted to present his Ph.D. thesis until the termination of the War.

In Germany, he had the rare opportunity of attending the lectures of Planck, Einstein, Rubens, Warburg, Franck, Hertz, Pohl, Born and others. He also attended the colloquium presided over by Rubens and attended by leading physicists and physical chemists of Germany. It was an exciting period when new developments in quantum theory by Planck, Einstein and Sommerfeld were taking place. Lively debates on Einstein's Special Relativity theory were going on, while his Generalised Relativity theory was being developed.

It was a period when new phenomena were being discovered, but not clearly understood. Chemistry and Physics seemed wide apart. The atom was a concept of chemistry—the atoms of Gold, of Oxygen, of Silver were different specific entities whose existence was noted, but not understood. Physics on the other hand, was a science of general properties of motion, of strain and stress, of electric and magnetic fields. It was not yet possible to answer the question : "Where do the properties of matter come from ?" At this point, Niels Böhr emerged and introduced the concept of quantum state—a concept which had already been prepared by Planck and Einstein.

Bose obtained his Ph.D. (*magna cum laude*) degree from the Berlin University in March 1919. However, he had to wait in London for a couple of months, before he could obtain a passage back to India. He returned to Calcutta in July 1919, and resumed his work at the Calcutta University.

Professional Career

The University College of Science and Technology, of the Calcutta University at 92, Upper Circular Road, was opened in 1916 under the dynamic leadership of its Vice-

Chancellor, Sir Asutosh Mookerjee. This was made possible by the munificent donations of two eminent lawyers, Sir Taraknath Palit and Sir Rash Behari Ghosh. It was intended only for post-graduate studies and research in certain sciences. The Department of Physics had C. V. Raman as Palit Professor and D. M. Bose as Ghosh Professor, besides a number of brilliant lecturers like P. N. Ghosh, S. N. Bose, M. N. Saha and S. K. Mitra. Dr D. M. Bose used to teach Kinematics, Statistical Mechanics and X-rays. In teaching, he usually followed Max Planck's method of exposition of a subject matter, while for guidance in research work, he tried to follow the foosteps of J. J. Thomson.

He combined within himself, British punctuality and German thoroughness. Following the tradition of Cavendish Laboratory, he had accommodated about a dozen research workers in only two rooms and used to visit each separately, everyday at fixed periods. One could set one's watch in consonance with his daily rounds. He held the Ghosh chair at the Calcutta University from 1914 to 1935. During this period, he was once offered a professorship at the Dacca University, which he declined. The next incumbent was Professor S. N. Bose.

In 1935, Sir C. V. Raman left for Bangalore as Director of the Indian Institute of Science. Dr D. M. Bose succeeded him as Palit Professor of Physics. After a couple of years, his uncle, Sir J. C. Bose, passed away and Dr D. M. Bose joined the Bose Institute as Director in 1938. He served the Institute with rare distinction for about three decades and retired in 1967, when his health began to fail.

Professor D. M. Bose was President of the Physics Section of the Indian Science Congress Association in 1927. The same year, in August, he attended the International Congress of Physics at Como, Italy, held in connection with the Volta centenary. Professor M. N. Saha also attended the congress as a co-delegate. Professor Bose revisited London in 1933, as an Indian delegate to an International Congress on 'Liquid Crystals.'

He was one of the founders of the Indian Physical Society and served the body in various capacities. He was a life-member of the Indian Association for the Cultivation of Science, which he served on many occasions, either as Vice-President or as member of its council. He was elected General President of the Indian Science Congress Association in 1952. He was also the President of the Asiatic Society of Bengal. He took an active part in promoting the cause of the Indian Science News Association, of which he was also the President. For several years, he was Editor-in-Chief of *Science and Culture*, started by Professor M. N. Saha. He held this position till his death.

Scientific Investigations and Contributions to New Knowledge

Professor Bose's research activities may be broadly classified under three principal heads :

(A) Study of nuclear collisions and disintegration by means of Wilson cloud chamber and photographic emulsions. Initiation of research activity in India in the fields of Cosmic rays, artificial radioactivity and Neutron Physics. Determination of the mass of mu-mesons by the Photographic emulsion method.

(B) The study of properties of simple and complex compounds containing paramagnetic and rare-earth ions. Interpretation of their magnetic moments in terms of Böhr's magneton. Origin of colour of such paramagnetic ions in crystals. Discovery of a new photomagnetic effect.

(C) Extension of Sir J. C. Bose's plant physiology investigations.

Cloud Chamber Investigations

Much of the earlier investigations of Bose was associated with the use of cloud chamber. As a student in the Cavendish Laboratory, he had seen C. T. R. Wilson develop this technique of employing the cloud chamber for photographing the tracks of ionizing particles. He was investigating the nature of condensing nuclei produced by an incandescent platinum wire in a glass bulb saturated with water vapour. The condensation was a complex process and the study did not yield significant results. In Berlin, he was given, by Professor Regener, the problem of devising a new type of Wilson Chamber. Bose was able to verify the formula given by Darwin for interpreting such collision effects. He also made some studies on delta-particles, the discovery of which had just been announced by Bumstead.

In this connection, a very interesting letter was received from T. J. Trenn from the University of Regensburg in West Germany, in November 1973, a true copy of which is reproduced below :

Universität Regensburg
WA bei Lehrstuhl für
allgemine Wissenschaftgeschichte

8400 *Regensburg*
West Germany
Universitätstrasse 31
Postfach
Telefon (0941) 9431
7 *November*, 1973

Dr D. M. Bose
History of Science Unit
Indian National Science Academy
Bahadur Shah Zafar Marg
New Delhi-2.

Dear Dr Bose:

I am completing an historical analysis of the use of cloud chamber techniques. One of the earlier successful results was obtained by one Debendra Bose then working in Berlin. This was done during the period 1914–1918, *and published later in* Zeitschrift für Physik, **12** (1723), 207–217. *Preliminary results appeared in* Physikalische Zeitschrift, **17** (1916), 388–390.

Now with a slight change this Debendra Bose would appear as Devendra. Is this in fact one and the same person ?

Debendra = Devendra = Devendramohan = Devendra Mohan = D. M. Bose.

His work published in 1923 *was particularly interesting, since the Figure* 4*C, on page* 212 *of that publication appears possibly to have been a case of artificial disintegration. If so, then it is an anticipation of the work of Blackett. The* 1916 *publication dealing with recoil* (*in contrast with artificial disintegration*) *clearly anticipates the work of Blackett.*

Any information that you might be able to provide on the identity and contribution of Debendra Bose would be gratefully appreciated.

SINCERELY
Sd/- THADDENS J. TRENN

After his return to Calcutta, D. M. Bose continued his investigations with an indigenously constructed cloud chamber. Along with S. K. Ghosh, he took photographs of recoil tracks of radioactive nuclei during the process of α-particle emission, and of the simultaneous emission of two ionizing electron tracks from a helium atom, due to collision with an α-particle. One photograph obtained by them was interpreted as showing the disintegration of a nitrogen nucleus. This photograph published in *Nature* (1923) elicited a warm letter of apreciation from Lord Rutherford. This line of investigation was interrupted by the accidental death of S. K. Ghosh.

Subsequently, H. P. De studied the polarisation of X-rays with the help of a cloud chamber. He also obtained an early evidence of electron-position pair production in lead by γ-rays from mesothorium.

Investigations on cosmic ray showers with counter-controlled large cloud chamber were initiated at the Bose Institute by Dr R. L. Sen Gupta and M. S. Sinha. Later on, Dr Sinha made significant contributions in this field.

Investigation in Magnetism

1919 was a period of feverish activity in the realm of Physical Science due to the formulation and development of Böhr's quantum theory of atomic structure. It attracted the attention and stimulated the interest of students of physical and chemical science all over the world. Bose, with his training as a physicist, naturally did not fail to participate in this new development. He turned his attention to the study of magnetic properties of chemical substances containing mainly paramagnetic ions of the elements of the first transition group of the periodic table.

Based on Böhr's theory of the distribution of electrons in the successive shells surrounding the nuclear charge in an atom or ion, it became possible to calculate the spectroscopic terms of an atom or anion in its ground and excited states and to calculate the nature of their emissions and absorption spectra. Hund (1925) showed how the magnetic moment of an ion with incomplete shell could be calculated from the theoretically determined spectroscopic term of its ground state. In the case of the rare earth group of ions in a solution or a crystal, in which the inner shell is protected from the influence of the surrounding atomic groups, the values of the magnetic moment calculated by Hund were found to be in excellent agreement with the experimentally determined values. On the other hand, Hund's formula completely failed to represent the magnetic moment of the iron group of elements.

Semi-empirically, it was shown by Bose (1927) that a better agreement could be reached, if it was assumed that for such paramagnetic ions, only the electron spin moment contributed to the magnetic moment. The calculated value of the magnetic moment of compounds of transition elements due to orbital and spin

motions is :—

$\mu_{S+L} = [4\ S\ (S+1) + L(L+1)]^{1/2}$ Böhr magneton. The magnetic moments of compounds of elements of the first transition series (Ti to Cu) agree well with the 'spin-only' formula, to which attention was drawn by Bose (1927) from a consideration of experimental values. The theoretical explanation for this was offered by Stoner (1929) and by Van Vleck (1935). The 'spin-only' formula is known as 'Bose Stoner' formula :

$$\mu_S = [4S\,(S+1)]^{1/2}$$

This is based on the assumption that the contribution to the magnetic moment by the orbital motion of the electron is more or less quenched by the influence of the field of the neighbouring atoms and ions. In the case of compounds of bivalent Fe^{++}, Co^{++}, Ni^{++} and Cu^{++}, the values are slightly higher than those predicted by the fomula due to incomplete quenching of the orbital moment.

D. M. Bose and his students, H. G. Bhar, S. Datta and others, also measured the magnetic susceptibilities of a large number of compounds belonging to the different transition group of elements, ranging from simple ionic compounds to the more complex ones, whose valency states had been studied by Werner. In his laboratory at that time, Bose had set up a modified Curie balance for making magnetic measurements. Professor P. Rây (1928) had also been engaged in the study of chemistry and structure of coordination complexes in the department of inorganic chemistry. Thus, the collaboration between Bose and Rây yielded many fruitful results in the field of magneto-chemistry.

In a paper by Rosenbohm (1919), the values of magnetic moments were given from his magnetic measurements on a number of complex (coordination) compounds. Bose (1925) pointed out, from a consideration of magnetic properties of many of these coordination compounds, that many of them, in which the *effective atomic number* of the central atom is equal to the atomic number of the nearest inert gas, should be diamagnetic, while those in which it differed should show paramagnetism, corresponding to the number of unpaired electrons equal to their difference. A similar suggestion was made by Welo and Baudisch (1925) in the same year. It was found that Bose-Welo's rule failed in a large number of complex nickel and cobalt compounds. The discrepancy arose from the fact that the nature of valency force in all varieties of complexes, perfect or imperfect, was believed to be of the covalent type. Later on, two different classes, represented as 'inner orbital' and 'outer orbital' types, were formulated as a result of subsequent development in the theory of the nature of valency forces.

A quantum mechanical theoretical interpretation of the magnetic properties of compounds of the iron group of elements, was proposed by Van Vleck. Following Hans Bethe, he showed that most of these compounds had generally six molecules of water or other equivalent dipole molecules arranged in octahedral symmetry surrounding the central ion. Due to the interaction between the charge on the central ion with the surrounding dipole molecules, a Stark electric field of predominantly cubic symmetry acted on the central ion; the spin-orbital coupling in the valency shell of the paramagnetic ion was broken up and the state of degeneracy of the orbital moment L of the ion was broken and the ion could have $L + 1$ virtual orbital levels. If for the ground level $L = 0$, the ion has a magnetic moment due

only to the Vector sum of the spin magnetic moments of the electrons in the *D*-shell. The agreement between the theoretical and calculated values was found to be generally satisfactory, except for Co^{++}. For this ion, Van Vleck (1935) felt that orbital states were probably inverted.

A large number of compounds of the transitional group which have four to six atomic groups like NH_3, CN, CO & C around the paramagnetic ion have been found to be diamagnetic. On the assumption that each of these co-ordinating groups shared two covalent bonds with the central paramagnetic ion, Bose formulated an empirical rule for predicting the magnetic moments of the six-fold and four fold-coordination compounds. With some exceptions this rule was found to hold good for most coordinate compounds. A theory of molecular orbitals and its alternate formulations by Mulliken, Hund, Van Vleck and others, gives a quantum mechanical interpretation of the chemical and magnetic properties of this group of compounds.

In another series of experiments, D. M. Bose with some of his pupils attempted to find the experimental proof of Bethe-Van Vleck's theory of the splitting up of the degenerate orbital quantum number of a paramagnetic ion into $L + 1$ equidistant energy levels in the Stark field. The transition between the ground level and any one of the higher levels would result in the absorption of energy from the incident white light and reveal absorption bands. D. M. Bose and his collaborators collected a large number of observational data, supplemented by their own observations on the absorption spectra of crystals and solutions containing paramagnetic ions, ranging from Ti to Cu in different valency states. They could show that the frequencies $\triangle\nu$ of these absorption bands, varying in number from one to four, of these different ions could be represented by an empirical formula

$$\triangle\nu = \triangle L.\ Ze.\ f.\ K_0,$$

where Ze = Ionic charge,

$\triangle L$ = Change of the orbital quantum number of the ion due to light absorption,

f = Polarisability of the associated dipole molecules

and K_0 = a constant, whose value under certain assumptions could be calculated.

In this line of investigation S. Datta, M. Deb and P. C. Mukherjee participated.

One of the consequnces of the splitting up of the degenerate orbital quantum number of a paramagnetic ion in the Stark field of the surrounding molecular groups, was the discovery of a new photo-magnetic effect. If it is assumed that for the ground state of the ion in the Stark field, $L = 0$, then due to light absorption the ion will be raised to a state with orbital number 1, 2 etc. This will result in an increase following light absorption in the orbital paramagnetic moment of the ion in solution. D. M. Bose with P. K. Raha, devised an experimental arrangement to test this theoretical prediction. In all instances, where the effect was observed, it represented an increase in the susceptibility of the paramagnetic solution under light absorption. One of the results obtained may be quoted as :

"The photomagnetic effect in aqueous solutions containing ions of Ni^{++}, Cr^{+++} *and* Co^{++} *have been measured quantitatively; their magnitudes for the same amount*

of light absorbed are found to diminish in the order in which the ions are arranged. It is found that the effect is roughly proportional to the quenching of the orbital moments of these ions in their ground states."

A certain number of other magnetic measurements were carried out under Dr D. M. Bose's guidance at the University College of Science, Calcutta. D. P. Rai Chowdhury measured the gyromagnetic ratio in certain ferromagnetic oxides and found it to be nearly 2, which indicated that the spin value only of the *d*-electrons contributed to the ferromagnetic moment. S. D. Chatterjee investigated the influence of magnetic field on the co-efficient of viscosity and on the dielectric constant of liquids. K. P. Ghosh measured the change in the electrical conductivity of iron oxide haematite when it passes from ferromagnetic to the paramagnetic state. This was a qualitative verification of Heisenberg's theory of ferro-magnetism.

Photographic Emulsion Work

From 1938, after joining the Bose Institute, Bose took up the study of tracks of cosmic ray ionizing particles using the photographic emulsion technique. His interest was aroused by a discussion with Walther Bothe during the Science Congress Session of 1938, in Calcutta, when H. J. Taylor read a paper on the use of photographic emulsion for the study of cosmic radiation at high altitudes. Between 1939 and 1942, together with Bibha Choudhuri, Bose exposed a large number of Ilford's new half-tone plates to cosmic rays at high altitudes between 7,000 ft. and 14,000 ft. at Darjeeling, Sandakphu and Pharijong, under different absorbing materials like lead and paraffin. They observed a number of long, curved ionisation tracks, which appeared to be different from those due to α-particles and protons. They were able to prove that such tracks were due to mesons. For the purpose of verification, a method of determining the mass of such track producing particles, by measuring their mean scattering and mean grain spacing was developed. The mean value of the meson mass found by them was $(216 \pm 40)me$, as compared to the subsequently determined value of the mass of the mu-meson $(213 \pm 15)me$, following Powell's discovery in 1947, of two kinds of mesons, the μ and π mesons, with masses of the order of $214me$ and $290me$ respectively. It was also proved that the proton/neutron component of cosmic rays was largely responsible for meson production. With the departure of Bibha Choudhuri to England in 1945, this work was discontinued as it was felt that further investigations were only possible after the preparation of improved types of photographic emulsion. Later on, Powell in collaboration with M/s. Ilford & Co., was able to prepare such improved emulsions. It may be noted that Powell was awarded the Nobel Prize for his investigations along this line. He actually acknowledged the priority of Bose and Choudhuri's work about μ-mesons during the course of his lecture at Bose Institute sometime later.

Further Work on Cosmic Rays, Nuclear Physics and Radiochemistry

The east-west asymmetry of cosmic radiation was measured for the first time in India with G-M counter technique by R. Ghosh at the Bose Institute in 1937-39,

Subsequently, the time-variation and altitude-dependence of cosmic rays were measured by S. D. Chatterjee and I. L. Chakrabarti, using a Compton-Bennet type of Ionization Chamber. Several interesting cases of sudden variations in cosmic ray intensity associated with solar flares and magnetic storms were recorded. In 1940, S. D. Chatterjee measured the intensity of the neutron component of cosmic-rays at Calcutta and Darjeeling, using Boron-lined proportional counters.

In 1940s, Bose sponsored researches in Nuclear Physics and Radiochemistry. Using a meagre 60mc (Ra + Be) source, measurements in artificial radioactivity were originally started by N. K. Saha, S. D. Chatterjee and others. In particular, S. D. Chatterjee and P. Rây were able to isolate chemically Co^{60} (~5.3 year half-life) from sodium cobalticyanide complex compound. Using radioactive iodine I^{128}, they also established that there was no essential difference between normal co-valency and coordinate covalency. Later, S. D. Chatterjee detected spontaneous fission of uranium and measured its half-life, without any knowledge of similar work being done by Petrzhak and Flerov in U.S.S.R. during World War II. Along with P. B. Sarkar, he also identified diverse fission fragments in an old uraninite mineral, whose life was determined to be ~836 million years by U : Pb ratio. For further work in neutron physics, a 14.5 MeV neutron generator was fabricated and operated at the Bose Institute by A. N. Banerjee, A. M. Ghose, N. K. Ganguli, B. Mitra and others. Incidentally, it happens to be the first instrument of its kind to be installed in India, under D. M. Bose's guidance.

Plant-Physiological Investigations

Professor Bose made a special study of the plant physiological investigations of Sir J. C. Bose. As a result, he published a monograph entitled : *J. C. Bose's Plant Physiological Investigations in the Light of Modern Biological Knowledge.* He came to the conclusion that his predecessor's plant physiological investigations were mainly of a biophysical nature and required to be supplemented by biochemical ones, in which, biochemical processes intervening between stimulation and mechanical response in plants had to be established. He initiated the investigation regarding the source of energy of mechanical response in plant organs, including the spontaneous pulsation of leaflets of *Desmodium gyrans,* and the mechanism of the transference of energy released by carbohydrate oxidation in the motile plant organ. In a review article contributed to the Silver Jubilee Celebration volume of the *Proceedings of the National Institute of Sciences of India* entitled : 'Plant physiological and cytological investigations on Plants with motile organs,' D. M. Bose reviewed the progress of work on these subjects, carried out in the Bose Institute.

In his presidential address, at the Indian Science Congress in 1953, he gave a connected account of the evidence in our knowledge of the relation between the living and non-living, following the jubilee of the publication in 1902 of Sir J. C. Bose's monograph on "Responses in the Living and Non-living."

Thus, both as Professor of Physics in the University College of Science and as Director of the Bose Institute, D. M. Bose trained, activated and inspired a generation of scientists in their own lines of investigation and has possibly catalyzed many more.

Marriage, Wife and Children

In 1919, after his return from Europe, Dr D. M. Bose married Srimati Nalini Sircar, the eldest daughter of Sir Nil Ratan Sircar, one of the foremost physicians of his time. Mrs Nalini Bose is a versatile linguist and also a exponent of European classical music on the piano and violin. Together with her husband, she has collected a library of records of classical music. D. M. Bose was indeed fortunate in having such a talented helpmate. None can fail to recognise the greatness of her share in his life's productivity and success. She was a worthy consort of her scientist husband through the manyfold phases of his life.

They have three sons in Debabrata Bose, Sunanda Bose and the late Supriya Bose, The eldest son, Debabrata Bose, took an M. A. degree in English from the Calcutta University and worked for a while at the Indian Statistical Institute under Professor P. C. Mahalanobis. Later he went to U. K., and worked for another M. A. degree in Anthropology, from the London University. He also graduated from the British Institute of Management. He is now keenly interested in problems of industrial and business management in our country. He is, at present, a member of the Governing body of the Bose Institute and a Trustee of the Sir J. C. Bose Trust (I).

The second son, Dr Sunanda Bose took his M. Sc. degree in Botany from the Calcutta University in 1947. He visited Sweden and collaborated with Professor Arne Muntzing at the Institute of Genetics in Lund. In 1958, he got the Filosofie Doctorate (Fil. dr.) in Genetics from the University of Lund. Returning home, he joined the Bose Institute as Senior Research Fellow. Since 1961, he has been working as a Professor and Head of the Department of Botany at the Bose Institute.

The youngest son, Supriya Bose, was a student of Physics at the Presidency College and was earmarked to follow the footsteps of his illustrious father. Unfortunately, he died at an early age in an accident, a loss which deeply affected his parents.

D. M. Bose is survived by his ailing wife and two sons.

Glimpses of his Personal Life

In his *Modern Science and Modern Man,* James B. Conant observes that '*the notion that a scientist is a cool, impartial, detached individual is, of course, absurd. The vehemence of conviction, the pride of authorship burn as fiercely among scientists as among any creative workers.*' This apparent contradiction may be explained by the hypothesis that though *'science is ordered technique,'* it began as *'rationalized mythology.'* Indeed Professor J. D. Bernal reminds us that *'it started as a hardly distinguishable aspect of the mystery of the craftsmen and the lore of the priest.'*

The most attractive feature in the life of D. M. Bose is the blend therein of the orient and the occident. This has been due to the influence of Sister Nivedita in India and of Miss Jane Hay in Scotland during his early life and subsequent long residence in Germany during World War I. He combined eastern meditativeness with the western belief in the inscrutability of Nature. His preoccupation with scientific research, however never forced him to abandon that essential humanism which characterizes all creative thinkers.

Those who have known Professor D. M. Bose during his professional career will hardly believe that from his childhood, Bose was interested in all those activities of any healthy boy of his age. For example, very few people know that he was a versatile sportsman. He was one of the founders of the Sporting Union Club, which in this land of temporary enthusiasms, has had a miraculous life of more than eight decades. Young Bose, was the captain of the hockey team of the Sporting Union Club in 1905–06. While a student of the Presidency College he excelled in cycling, football and cricket. He won several trophies in these activities and used to recall with pleasure that he was a member of the team which won the Elliott Shield for Presidency College.

Unfortunately, his movements became very much restricted during his four years' internment in Germany (1914–18) due to the First World War. The severe winter of Berlin took its toll and D. M. Bose was overtaken by the common family disease—arthritis. It crippled him to some extent and remained as his constant companion for the rest of his life. In course of time, he became a recluse and instead of taking long walks, as he used to do, he began spending his vacations in solitude, amidst scenes of natural beauty, like Mayapuri, Darjeeling, and the riverside bungalow at Falta. The present writer had the unique opportunity of spending about a month at Mayapuri, Darjeeling, in connection with cosmic ray investigations. Although he stayed in the same building, he rarely had the opportunity of meeting Dr D. M. Bose and discussing his problem. He saw him occasionally from a distance, sitting alone and aloof from the excitements of the world. He usually sat on a reclining chair in the garden, surrounded by smiling flowers and dancing leaves. Not a voice was there to jar upon the ear; not a footstep to disturb the stillness of that solemn eventide. He sat in solitude, watching the birds that soared overhead, the clouds that rested along the horizon; enjoying the cool caresses of the evening breeze, until darkness deepened. And then he would move inside the bungalow, light a lamp and immerse himself in reading books, which were his constant delight.

In Calcutta, he usually walked the short distance between his residence and the Bose Institute a few times everyday. He avoided both the limelight of public applause and the patronage of the powers that be.

Nevertheless, D. M. Bose did not confine his activities within the narrow limits of his field of science. He always took a keen interest in the progress of social and cultural organizations of the country. He was closely associated with the management of the City College and the Sadharan Brahmo Samaj. As its Honorary Treasurer, he served the Viswa-Bharati for about 18 years. He was one of the sponsors of the Indian Physical Society and served it in various capacities. He was a life-member of the Indian Association for the Cultivation of Science, which he served on many occasions as Vice-President or Member of its Council. He took an active interest in promoting the cause of the Indian Science News Association, of which he was the Patron and President for sometime. For several years, he had been the Editor-in-Chief of its journal, *Science and Culture,* a position which he held till his death. His own desire for concreteness in the picture, combined with a forceful style made him a particularly clear writer and expositor.

D. M. Bose was deeply interested in the History of Science. He was a member, and later convener of the History of the Science Board set up by the Indian National Science Academy. In 1965, the Board was replaced by the National Commission, for the compilation of History of Science in India, of which he became the first convener. He was one of the editors-in-chief of "*A Concise History of Science of India,*" a prestigious publication of the Academy. He was also the editor-in-chief of the *Indian Journal of History of Science*, (published by the Academy under the auspices of the National Commission) a task he carried out with great zeal, care and thoroughness.

He was President of the Physics Section of the Indian Science Congress in 1927 and its General President in 1953. He was also elected President of the Asiatic Society of Bengal on two occasions.

Bose was recipient of numerous honours in his own country and abroad, which included D.Sc. (*Honoris causa*), Calcutta University (1969), D.Sc. (*Honoris causa*) Jadavpur University (1969) and Deshikottama of Vishwabharati University. He has been responsible for the inspiration planted in the hearts of his numerous pupils and friends, who have been vouchsafed a wider view of nature through what he has written and spoken.

Bose was a man of few words, and a more or less silent worker, inspite of his vast erudition and wide interest. Towards the younger workers of the Bose Institute he used to entertain a sincere sympathy for their progress and welfare in life' in spite of his insistence on discipline and devotion to duty. To all his colleagues, pupils and friends, and to all those who happened to come in close contact with him, he will be remembered particularly as a strikingly handsome figure of dignified personality. His unassuming nature and his uncompromising principles were praiseworthy.

After his retirement from the Bose Institute, his health steadily deteriorated. Death came to him during the morning hours of June 2 1975. One recalls Tennyson's words, "*God's finger touched him and he slept.*"

Thus a commanding figure in the annals of Indian Science has gone to rest.

S. D. CHATTERJEE

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TIRUVENKATA RAJENDRA SESHADRI

(1900–1975)

Elected F.N.I. 1942

Birth, Parentage and Early Life

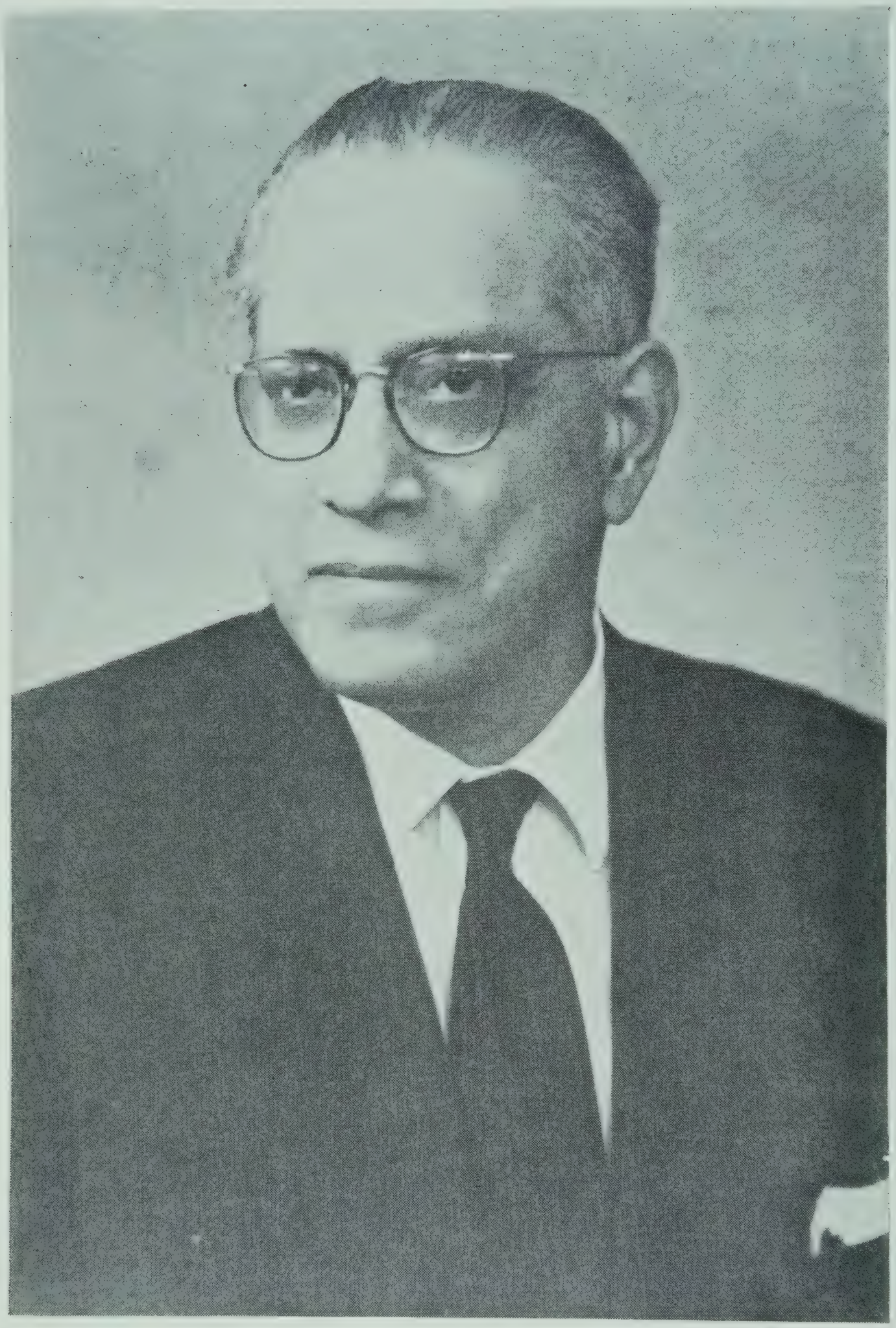
Thiruvenkata Rajendra Seshadri was born on February 3, 1900 to Thiruvengadatha Iyengar and Namagiri Ammal at Kulitalai, situated on the bank of river Kaveri in Tiruchy district of Tamil Nadu in South India. Seshadri's father was a teacher in a local school and the family was known for its piety. Seshadri was the third of the five sons. He went to the National College High School in Tiruchy city, founded by men imbued with high patriotic fervour. Life in this school naturally left a deep impression all its alumni.

Higher Education

In India

In 1917, Seshadri moved to the metropolitan city of Madras and joined the Presidency College, a seat of higher learning founded by the British. There he came under the influence of some very inspiring teachers of Chemistry; he carried fond memories of his teacher, Professor P. A. Narayana Iyer. Cost of living in large metropolitan cities was high even in those days and even with the merit scholarship Seshadri received, his college education became a financial strain on his family. He, therefore, had to look for relief and this came from the Ramakrishna Mission, which admitted Seshadri to its Students' Home. The association with the Ramakrishna Mission was to have a lasting effect on Seshadri. The discipline in the Students' Home, the simple living and high thinking practised there, the dedication, sense of duty and the spiritual atmosphere prevailing there, shaped Seshadri's life in a manner no other institution could have done. Seshadri remained adherent to ideals of the Ramakrishna Mission throughout his life.

After receiving the Honours degree in Chemistry of the University of Madras, Seshadri worked with the Ramakrishna Mission for one year, helping in the organisation in their new Residential High School. Later, he joined the Chemistry Department of the Presidency College, Madras, as a University Research Scholar, under the guidance of its head, (the late) Professor B. B. Dey. For his work which was partly on Indian medicinal plants and partly on coumarins, the University of Madras awarded him two prizes, the Sir William Wedderburn Prize and the Curzon Prize.



T. R. Seshadri

At Manchester, London, Graz, Edinburgh : 1927–30

In 1927, Seshadri secured an overseas technical scholarship from the Government of Madras and sailed to England to work at the University of Manchester under the celebrated Professor Robert Robinson (F.R.S.) who was attracting research workers from all over the world. Seshadri's Ph.D. thesis consisted of two parts : (1) Search for new antimalarials and (2) Synthesis of anthocyanins. Seshadri cherished his association with Robinson School as the most important event in his scientific career and felt that through this he had become a member of the great Perkin family of Organic Chemists. Seshadri's personal loyalty to Professor Robinson was very intense and unswerving, and it was fully and generously reciprocated by his great master, who considered Seshadri among his most outstanding pupils. In his message on the 60th birthday of Seshadri (1960) printed in the special souvenir volume, Professor Robinson wrote :

> "*Even if Professor Seshadri were known to me only as an author of original memoirs in the Chemical Journals, I would be gratified to have this opportunity to add my tribute to his fertility of ideas, his technical skill in execution and his qualities of energetic drive and wise planning. His original researches have indeed given him worldwide recognition and he is unsurpassed in the experimental survey of the groups of natural products on which he has concentrated his attention. But to me, he is no mere name in the literature; I have enjoyed the inestimable privilege of following his development almost from the beginning. His work in my laboratory, especially on the synthesis of anthocyanins, was of the highest calibre and went far to encourage us to pursue the attack in this difficult region of synthesis. It is not appropriate here to recount the outstanding achievements to the credit of Seshadri and his school; that is the purpose for which this volume is dedicated. Suffice it to say that we do homage to a most sincere scientist of unassailable integrity, a brilliant and devoted teacher and a most generous friend.*"

After receiving the Ph. D. degree of the University of Manchester and before returning to India, Seshadri worked for brief periods in other important centres in Europe. He spent some months in Graz in Austria learning organic microanalysis in the laboratory of Professor Fritz Pregl, the father of quantitative organic micro-analysis. This new technique reduced the quantity of organic substances required for analysis by a factor of nearly 20, and this contributed to the rapid progress in the chemistry of natural products in the decades that followed. It was for this significant contribution to organic chemistry that Professor Pregl was awarded the Nobel Prize, in 1923. Another laboratory where Seshadri worked for about eight months was that of Professor George Barger, F.R.S. who then occupied the Chair of Medical Chemistry at the University of Edinburgh. Here he was associated with work on the chemistry of retrorsine. This substance falls under the group of quinolizidine alkaloids, which received their full elucidation years later, and Seshadri contributed to the chemistry of this group in the mid sixties. Seshadri also spent a short period in the laboratory of Mr Cameron, Chief Agricultural

Analyst to the country of Fife, where he acquainted himself with methods of agricultural chemistry.

Coimbatore and Andhra University : The War Years

At the conclusion of his foreign training, Seshadri returned to India in 1930. The country was caught in the worst economic depression the world had seen; in addition, it was rocked by national struggle for freedom from British rule. Career openings were rare for qualified scientists. Seshadri chose to become a Research Fellow in the University of Madras and after some months joined a Government Research post in the Agricultural College and Research Institute at Coimbatore as a soil analyst. Although this institution afforded him opportunities to become acquainted with different aspects of agricultural science, particularly plant chemistry and plant protection, there was little scope for fundamental work. When three years later an opportunity arose, Seshadri joined the Andhra University at Waltair, as Senior Lecturer and Head of the new Chemistry Department. This called for a great deal of organisational work. Laboratories had to be built and equipped and courses of studies had to be framed. Starting from scratch, Seshadri built up a fine Department of a progressive university. While his laboratories were yet under construction, Seshadri used to rush on a bicycle to the Biochemistry Department of the Andhra Medical College at Visakhapatnam, three miles away, to do his own research. In 1934, Seshadri was appointed Reader and in 1937 Professor of Chemistry in the University. His zeal and dedication for research were so infective that a number of young men joined him. In 1937, he was also given the responsibility of looking after the University Department of Chemical Technology. The financial resources of the two departments were small by present-day standars, but by very prudent husbanding, they served to sustain the activities of a number of workers. 1937 was also the year when Seshadri laid the beginnings of the Department of Pharmaceutical Sciences of the Andhra University.

The laboratories that Professor Seshadri was building were beginning to take shape when the Second World War broke out (1939) and supplies of chemicals and scientific goods from Europe, on which educational institutions in India had largely to depend, became scarce. In 1941, came other restrictions, and laboratory work had to be curtailed. Towards the close of the academic year 1941–42, the harbour at Visakhapatnam, situated about 4 miles away from the University campus, was bombed by the Japanese. This necessitated the evacuation of the entire town of Visakhapatnam including Waltair and the University campus. The University buildings were commandeered by the Defence Department and the laboratories so laboriously built up over the years were dismantled and transformed into a military base hospital. All the University teaching departments and administrative offices were moved to a relatively safe inland location, Guntur, about 300 miles south, and accommodated in whatever buildings could be acquired on rent and in hastily put up temporary sheds. This was hardly satisfactory and the Chemistry Department of the Andhra University was shifted to Madras at the beginning of the academic year 1943–44. Class work was done in the Chemistry Department of the Presidency College and the Biochemical Research Laboratories of the University of Madras.

With this change, the setback to research experienced by the Chemistry Department during 1942–43 was partly overcome and work began to pick up once more. Even with all the restrictions imposed by the state of war, a remarkably large volume of research work was turned out and several young people were able to obtain their doctoral degrees.

The year 1945 saw the formal end of hostilities, and all the departments of the Andhra University moved back to Waltair at the commencement of the academic year 1946–47. However, the Chemistry laboratories had to be re-built, since they had been completely dismantled. The task of reconstruction was not easy as there was shortage of almost every item in the post-war years. The stoppage of scientific supplies from Europe that began at the commencement of the War turned out to be a permanent feature and the tardiness in the development of a fine chemical industry in the country plagued Indian Science for at least a decade after the War. Professor Seshadri's enthusiasm for research, however, never flagged and it is to the eternal credit of this undaunted and dedicated scientist that he continued to produce high class work in these manifestly adverse circumstances.

University of Delhi and the Advanced Centre for the Chemistry of Natural Products

Resettlement at Waltair was only just complete when Professor Seshadri had to face a moral crisis. The University of Delhi had formally been established in 1925 but had yet no teaching department of its own. The early forties saw some growth but it was only after Sir Maurice Gwyer become its Vice-Chancellor that real progress began. In 1949, he took a major decision to organise post-graduate teaching and research in the sciences. To achieve this, he looked for the best talent available in the country. Sir Maurice invited Professor Seshadri to head the Chemistry Department. It was not easy to leave the Andhra University where Seshadri had built up an active school of teaching and research. Also, Delhi University did not seem a propitious place initially. However, after weeks of indecision, Seshadri finally agreed to join the Delhi University in July 1949.

It did not take Professor Seshadri long to transform the Department into one of the most active centres in the country for research on the Chemistry of Natural Products. In this mission, he received support not only from Sir Maurice Gwyer but also his successors. In 1957–58, he received a gift of the much needed instruments like UV and IR spectrometers from USA under the Wheat Loan grants. These instruments had by then become indispensable aids and their availability stepped up the pace of research. The best equipment, however, was really the human material. A large number of intelligent and highly motivated young students joined him. To them Professor Seshadri set the pattern not only for Chemistry but also for dedication and other human values. The laboratories were kept open from early morning till late in the night and Professor Seshadri was always there to guide, advise and help. It was common knowledge that Professor Seshadri had no home or social life; he was always in the laboratory. Sustained work by competent and dedicated students led to a flow of high quality publications which appeared in the foremost of Indian and foreign scientific journals. The fifties were so productive that in 1960,

he received the high distinction of being elected Fellow of the Royal Society of London. That was also the year when he completed sixty years of age and his election was a fitting recognition of two decades of hard work.

In 1962, the University Grants Commission (UGC) selected Seshadri's Department as the Centre for Advanced study in the Chemistry of Natural Products in India and made him its first Director. It was with the organisation of this Advanced Centre that the author of this memoir was invited to join the Delhi University group. The Centre attained great distinction in the Chemistry of Natural Products ever since it came into existence.

Active Research In the Post-Retirement Years : 1965–75

In 1965, Professor Seshadri completed sixty five years of age and according to the rules of the University, he retired from all formal administrative positions and responsibilities in the Chemistry Department. The University, however, appointed him as its first-ever Emeritus Professor, thereby providing him with the possibility of continuing his researches. Many science funding agencies of the country such as the Council of Scientific and Industrial Research (CSIR), the Indian Council of Medical Research (ICMR), the Indian Council of Agricultural Research (ICAR) and the Indian National Science Academy entrusted him with important research projects. The U.S. Department of Agriculture also funded projects through their PL-480 programmes. These brought him adequate funds and support for a number of young scholars. Being freed of the administrative responsibilities, Seshadri could devote all his time to research.

Professor Seshadri suffered a massive heart attack in January 1965 which incapacitated him considerably, and, from which he recovered sufficiently to be able to carry on his work, though not with the same vigour as before. His dedication to chemistry was so great that in the post-retirement years the research publications practically doubled, with the result that when he died in 1975, he had around 1200 publications and had trained more than 150 Ph.Ds.

Professor Seshadri desired that young men and women should become good research scientists and in this he met with great success. Many who worked with him in the fifties are now leaders of research not only in India but also in several foreign countries. To mention only a few, Pofessors P. S. Rao, L. R. Row, K. Neelakantam, V. V. S. Murti, S. K. Mukerjee, A. C. Jain, S. Neelakantan, G. B. V. Subramanian V. K. Ahluwalia, Dr Varadarajan and Dr K. Aghoramurthy. The author of this memoir wrote with Professor Seshadri a book entitled, *Chemistry of Vitamins and Hormones* whose first edition appeared in 1946 and the second in 1952.

Professor Seshadri firmly believed that science alone cannot solve the problems of Man. His faith in moral and spiritual education was deep and abiding. Along with Swami Ranganathananda, then Chief of the Delhi Unit of the Ramakrishna Mission, he started the Delhi University Vedanta Samiti, which held regular Sunday morning meetings at which spiritual matters were discussed with the help of ancient texts of India and explained in terms of modern scientific concepts. Professor Seshadri strongly believed that the academic community had a special and unique responsibility to society, and that mere academic achievements divorced

from ethical, moral and spiritual moorings were a danger. He encouraged his students to participate in the activities of this study group.

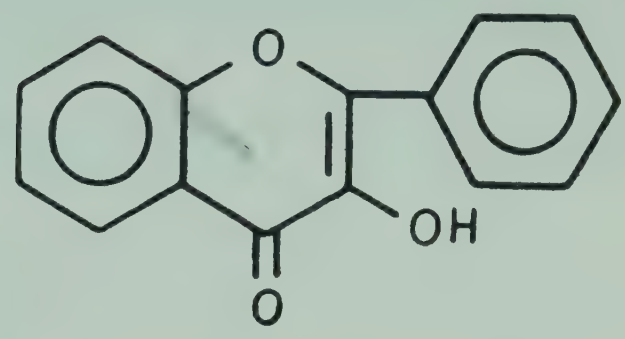
Service to Science in the National Sphere

Professor Seshadri's rich experience as a chemist and scientist was utilised by the scientific community and the Government of India in several ways. He was chairman or member of expert bodies of several Universities. He was member of the Pharmacy Council of India, Ministry of Health, Governing Body of Indian Council of Medical Research (ICMR) and Chairman of its Expert Committee on Indigenous Drugs. He was Chairman of the Chemical Research Council of the Council of Scientific and Industrial Research (CSIR), a member of its Governing Body, Chairman of the Executive Council of the Regional Research Laboratory, Jammu, Member of the Executive Council of the National Chemical Laboratory, Poona, and of the Regional Research Laboratory, Hyderabad (all under the CSIR). He was Chairman of several expert committees of ICMR, CSIR and the Indian Council of Agricultural Research (ICAR), the University Grants Commission (UGC) and the Ministry of Education and Scientific Research, the Ministry of Health, Ministry of Agriculture, Ministry of Defence and the Department of Atomic energy of the Government of India. He was Chairman of Review Committee of the Indian Institute of Science, Bangalore and of the Indian Lac Research Institute, Ranchi. He was a member of several committees for selection of candidates for foreign scholarships. He was a member of the Scientific Advisory Committee to the Cabinet and of the Committee on Science and Technology of the Government of India. For sometime, he was a consultant to the UNESCO.

Contributions to Scientific Knowledge

Oxygen Heterocyclics

Professor Seshadri, whose major contributions have been in the area of oxygen heterocyclics, began with the isolation and structure elucidation of the flavonoid pigments of Indian plants, both aglucones and glucosides, and developed methods of methylation to facilitate the degradative study of the aglucones to get an insight into the structure of the glucosides. For providing synthetic support to the structures of new members which have a higher degree of oxygenation, methods had to be evolved for introducing more hydroxyl groups into various positions. The converse procedure for removal of hydroxyl groups was also worked out. Methods of partial methylation and demethylation were also evolved as part of the strategy. These studies were extended from flavones and flavonols to insoflavones, flavanones, chalkones, aurones, isoflavanones, dihydroflavonols, xanthones and anthraquinones involving plant materials of various families and genera. Methods of total synthesis and interconversions in these areas were also elaborated. Further sophistication arose in many cases of natural compounds by the presence of C-methyl groups, C-prenyl groups, furan rings, chromene rings and combinations of these and methods were evolved for their study by classical and modern methods and synthesis.



FLAVONOL

The flavandiols called leucoanthocyanidins by Professor Seshadri had eluded isolation and study for decades. These and the catechins which are related to anthocyanidins and tannins are optically active and their chemistry and stereochemistry received considerable attention by the Seshadri Group.

Coumarins, halocoumarins, 3-phenyl-and 4-phenyl-coumarins and groups of natural compounds related to them also engaged the attention of the Seshadri school. Other groups of compounds derived from flavonoids or coumarins and characterised by the presence of an additional ring resulting from an oxide bridge connecting the pyrone ring and the side phenyl ring, bi-flavonoids and flavanolignans, which are of rather restricted natural occurrence, were additional areas of his research.

Professor Seshadri showed deep concern with the problems of his country and this led to his involvement with the rational utilisation of natural resources like medicinal plants, poisonous plants, dyestuff plants, insecticidal plants and other economic plants of the country like *Psoralea corylifolia, Pongamia glabra,* species of *Dalbergia, Pterocarpus, Acacia, Morinda, Albizzia, Gossypium, Cassia, Citrus* and *Pinus.*

Professor Seshadri was the pioneer Indian chemist who made an extensive chemical study of the lichens of India and their chemical components, involving degradation and synthesis.

After compiling a vast volume of data, it was a natural step to trace their evolution and propose theories of biogenesis. Professor Seshadri has propounded biogenetic theories on practically all the groups of compounds which came to his attention.

Methylation of Anthoxanthins and Glycosides

Sustained fundamental research by Professor Seshadri commenced at the laboratories of the Andhra University, Waltair, during the mid-thirties concerned the examination of the brightly coloured flowers of several species of cotton (*Gossypium*) plants (family Malvaceae). The studies were later enlarged to cover other genera of the Malvaceae, like *Hibiscus.* This belongs to compositae and *Thespesia.* A large number of individual compounds of the anthoxanthin group were isolated both as free aglycones and as glycosides. The aglycones were studied by the classical methods that had been developed in western laboratories involving alkaline degradation, oxidation etc; initially the free aglycones themselves were degraded, but later, it was found to be more advantageous to degrade the methyl ethers, since this enabled easier isolation and recognition of the degradation fragments. Methods of methylation, therefore, became important and assumed

even greater importance for the investigation of glycosides to locate the position of the sugar residue.

Earlier methods for methylation of anthoxanthins and their glycosides were not quite satisfactory. Methyl iodide is too volatile and costly, diazomethane is not only poisonous but does not succeed well with chelated hydroxyl groups. Seshadri developed the method of using dimethyl sulphate and anhydrous potassium carbonate in boiling acetone medium, which helped in achieving complete methylation of all phenolic hydroxyl groups including the chelated one at the 5th position. For ethylation, ethyl iodide or di-ethyl sulphate along with potassium carbonate was used. When it is necessary to retain the 5-OH free for further transformation, the above dimethyl sulphate/potassium carbonate method is obviously unsuitable. The study of gossypin, the 8-glucoside of gossypetin, provides a good example wherein these techniques have been employed.

During the last two decades or more, the recognition of the existence of free hydroxyl groups in flavonoids in different positions and indeed the recognition of the type of flavonoid itself have been largely systematised on the basis of UV-visible spectral study employing neutral solvents, followed by addition of traces of various reagents like sodium acetate, sodium methoxide, aluminium chloride, borax, etc. They have been regularly employed in the studies of the Seshadri school.

Oxidative and Selective Demethylation

Oxidative demethylation has been developed by the Seshadri school as an elegant synthetic tool in connection with the structure of many natural substances, e.g., gossypin and the quino-chalkones of *Didymocarpus pedicellata,* and has been extended to substances not easily accessible otherwise e.g., carthamidin and norkhellin.

Nuclear Oxidation and Reduction

The development of synthetic methods for nuclear oxidation and reduction was a natural corollary to the isolation of a large number of anthoxanthins with varying oxygenation patterns. These were needed to provide synthetic support to structures deduced from degradative studies and also to enable acceptance or rejection of theories of biogenesis of flavonoids and related compounds based initially on speculation. Professor Seshadri and his school developed two distinct methods for introducing a hydroxyl *para* or *ortho* to an existing hydroxyl. Such introduction has been possible both in simple aromatic structures, in flavonoid precursors (chalkones) and in the finished flavonoid structures. Potassium persulphate in a strongly alkaline medium was employed for introducing a para hydroxyl.

Introduction of a hydroxyl into the *ortho* position was effected in two stages; first a formyl was introduced into the *o*-position by heating with hexamine in glacial acetic acid (Duff reaction) or by the Gattermann reaction (in a few cases an acetyl was introduced by *o*-acetylation followed by Fries migration); the formyl (or acetyl) was subsequently replaced by hydroxyl by heating with alkaline hydrogen peroxide (Dakin oxidation). These methods found extensive application not only in the laboratories of Profesor Seshadri but in many other laboratories in the world studying oxygen heterocyclics.

Nuclear reduction in Professor Seshadri's laboratory has been achieved in ring A and in the side phenyl ring of anthoxanthins by selective tosylation of the hydroxyl to be reduced and hydrogenolysis of the tosyester. The reduction is achieved in the following order of positions : 7, 5, 3′ 4′. Nuclear reduction has been implicated in the biogenesis of several members of the flavonoid group of compounds.

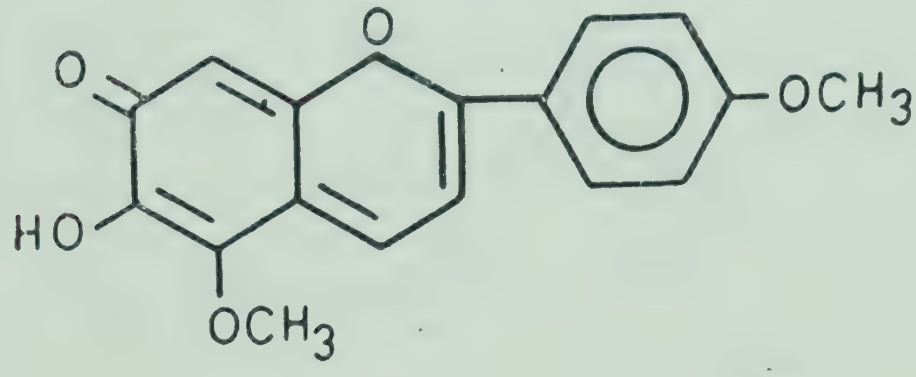
Anthocyanins, Leucoanthocyanidins and Qninonoid Anhydro Bases

Part of Seshadri's Ph.D work at Manchester was on the synthesis of anthocyanins. Of the four possible glucosides of pelargonidin chloride, the 3-glucoside (calistephin) had been synthesised earlier by Robertsonand Robinson* andSeshadri synthesised the remaining three. In the fifties, an intensive survey of anthocyanins was carried out at the Delhi University laboratories covering the flowers of many garden plants, avenue trees, forest trees and many edible fruits and agricultural cash crops. But the major thrust of the Seshadri school was in the area of leucoanthocyanidins (or pro-anthocyanidins as Professor Freudenberg would call them, with greater justification). Methods were evolved for getting good yields of anthocyanidins from other polyphenols. Intensely coloured compounds related to the leuco base of anthocyanidins and called quinonoid anhydro bases which had eluded precise understanding for decades also came under the scrutiny of the Seshadri school.

For the survey of anthocyanins, Seshadri and his coworkers employed the methods devised originally by Professor Robinson, like colour reactions and other qualitative tests, supplemented by new techniques that had come up like paper chromatography and absorption spectral studies.

Work in the area of leucoanthocyanidine has been difficult; even the isolation is tricky and crystallisation succeeds reasonably well only under fortuitous circumstances. When the pseudobase of a 7-hydroxy-flavylium salt i.e., 2,7-dihydroxy-flav-3-ene, undergoes loss of the elements of water involving the hydrogen of the 7-OH (leaving as H^+) and the OH at the 2-position (leaving as OH^-), a quinone methide structure results, in which the quinonoid conjugation extends to position 3 : 2, and into the side phenyl nucleus, resulting in deep colour. This is referred to as quinonoid anhydro base or quinone base. Compounds of this type are rather difficult to obtain crystalline. Two important natural quinonoid anhydro bases which have been obtained crystalline are carajurin and carajurone present in the cosmetic used by South American natives and called carajura (chica red) prepared from the plant *Bignonia chica*. In crystalline form carajurin is garnet red and carajurone scarlet red. They are related to the flavone scutellarein (4′, 5′, 6, 7-tetrahydroxyflavone). The pseudo base of the corresponding anthocyanidin scutellareinidin, when it loses the elements of water in the aforesaid manner, yields the red quinone base carajuretin (4′, 5, 6-trihydroxy-7-quinonoid base) which can also be obtained by demethylation of the natural substances carajurone which is its 4′-O-methyl ether or carajurin which is its 4′, 5-di-O-methyl ether. Professor Robinson had assigned the correct structure of carajurin as early as 1927, and Professor Seshadri provided synthetic support for it in the 1950's. 2, 4, 5-Trihydroxy-6-methoxybenzaldehyde (prepared by the para oxidation of 6-0-methyl-phloroglucinaldehyde) when condensed with

*Robertson, A., and Robinson, R. (1928) *J. chem. Soc.*, 1460.

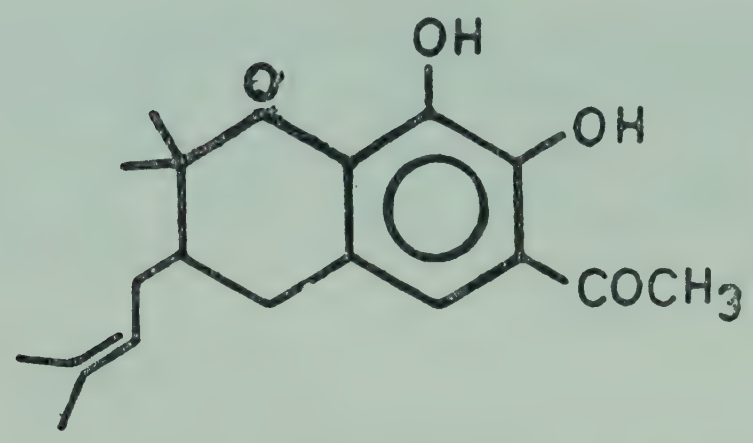


CARAJURIN

4-methoxyacetophenone and hydrogen chloride yielded carajuridin chloride (6 7 dihydroxy-5,4′-dimethoxy-flavylium chloride), treatment of which with sodium acetate yielded the anhydro base carajurin. Carajurin can be reconverted into the flavylium salt carajuridin chloride by the action of HCl.

Nuclear Methylation, Allylation and Prenylation

A large number of C-methylated benzopyrones have been discovered in nature, and to establish their identity synthetic C-methyl reference substances were needed. The early nuclear methylation studies began even in the late thirties and were extended during the subsequent two decades. Nuclear prenylated compounds both as such and in cyclised forms were discovered in abundance in nature during the sixties and this area of research stimulated Professor Seshadri's nuclear prenylation studies. These studies covered flavones, flavonols, chalkones, flavonones, isoflavones, xanthones and coumarins. Since 7-hydroxy-flavanones and -coumarins can undergo ring opening in the presence of base, they behave like resacetophenone. Where the pyrone ring is stable to alkali, the 7-hydroxy compounds fail to give the C-methyl derivative. Invariably some *o*-methyl derivatives are simultaneously produced. 5,7-dihydroxy-benzo-pyrones give the 6-C-methyl derivatives as expected. (Where direct C-methylation fails as with 7-hydroxy-flavone, a two-step method has been used with success, by introducing a formyl at position 8 using the Duff reaction and then reducing the formyl to methyl by catalytic hydrogenation. But this cannot be considered as real C-methylation). By such methods the following C-methyl compounds, among others, have been synthesised like for example , eugenitin, iso-eugenitin, iso-eugenitol, pino-querectin, angustifolionol and strobochrysin. C-prenylation has been studied extensively in the late sixties and early seventies. γγ-Dimethyl allyl bromide which gives *o*-prenyl derivatives with potassium carbonate in refluxing acetone, gives the C-prenyl derivatives in addition when the reaction is carried out in the presence of methanolic sodium methoxide, and only the C-prenyl compound with butyl lithium in benzene. 2-Methyl-but-3-en-2-ol in the presence of boron trifluoride-etherate has been extensively used to achieve C-prenylation. C-prenylation has been very successfully achieved with suitably substituted aromatic compounds, benzo-α-pyrones and benzo-γ-pyrones. Prenylation could be simultaneously achieved both in the benzene ring and side phenyl ring in flavonoids and occasionally two prenyls entered the same position, the nucleus reacting in the diketo form. The initial *o*-hydroxy-prenyl derivative could be cyclised using acidic reagents to yield a 2′-isopropyl-dihydrofuran or a 2′ 2′-dimethyl-dihydropyran, which on subsequent



dehydrogenation with DDQ gives the isopropyl furan or a dimethyl-pyran. A unique reaction was noticed with gallacetophenone. The first Pr unit entered the 5-position as expected, but it attracted a second prenyl at its 2′-position and simultaneously itself underwent cyclisation to dimethylchroman, the resulting product being 2, 2-dimethyl-3-prenyl-6-acetyl-7, 8-dihydroxy-benzochroman.

Studies on the Wesseley-Moser Rearrangement

Rearrangement of 5, 8-hydroxyflavones to the 5, 6-isomers and of 5, 7, 8-trihydroxy flavones to 5, 6, 7-isomers during attempted demethylation of the methyl ethers by boiling with hydriodic acid, has been known as the Wesseley-Moser rearrangement. Professor Seshadri and his coworkers made extensive studies with different oxygen heterocyclics which led to an understanding of the structural features influencing the change and to the synthesis, among others, of muningin and hinokiflavone.

2′-Benzyloxy chalkones give the epoxides by the action of alkaline hydrogen peroxide. When subjected to the action of acidic reagents like boron tri-fluoride-etherate or etheral hydrogen chloride these epoxides give different products depending on the substituents in the two aromatic rings and the experimental conditions. Two of the major products are the dihydroflavonol and the α-formyl deoxybenzoin which on cyclisation gave the isoflavone.

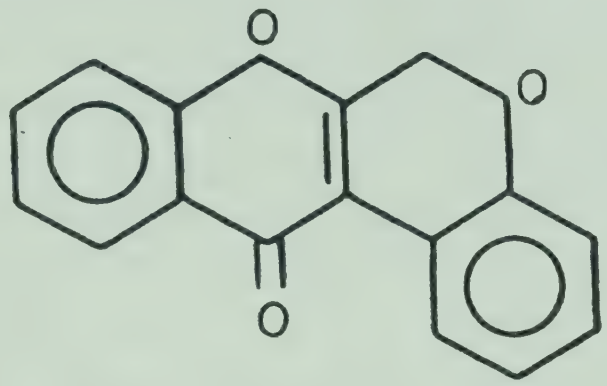
Synthesis of Furano-Chromones, Chromeno-Chromones, Chromeno-Flavones, etc.

Furano-chromone, chromeno-flavone and furano-chromeno-chromone are structures present in many substances having physiological activity. The earliest substance in this group that came to the attention of Seshadri was Karanjin isolated from the seed oil of *Pongamia glabra*. The structure of this substance had been established as 3-methoxy-furano (2′, 3′, 7, 8)-flavone by Professor Spath. In connection with its synthesis, Seshadri developed methods for construction of a furan ring on to chromones, flavones, coumarine etc. and conversely of an α- or γ-pyrone ring on to a benzofuran.

Further, similar method was followed for the synthesis of the linear furano-chromone khellin (the active principle of *Ammi visnaga*) which is 2-methyl-5, 8-dimethoxy-furano (2′ 3′ 7′, 6)-chromone. Starting from 2-methyl-5, 7-dihydroxy-chromone, the 7-0-acetic ester was prepared, another hydroxyl was introduced into the 8-position by *p*-oxidation, and a formyl group into the 6-position. Cyclisation of

the 5,8-dimethyl ether with acetic anhydride/sodium acetate was accompanied by decarboxylation and yielded khellin.

The isolation of several α, α-dimethylchromenes from natural sources led to synthetic attempts in this field. An aromatic hydroxyl is converted into the 1,1-dimethyl propargyl ether by heating with 3-chloro (or bromo) 3-methyl-but-1-yne in acetone solution with anhydrous potassium carbonate and in the presence of potassium iodide. The propargyl ether side chain cyclises to the α, α-dimethyl-chromene on heating in a high boiling solvent like dimethylaniline. In the flavonoid field, in general, the angular isomers are the major products and linear isomers the minor. In rare cases spontaneous cyclisation takes place, at least partially, even during the formation of the ether. In an alternative route, the propargyl ether was partially hydrogenated, ring closed by the action of acidic reagents to give a pyran ring and then dehydrogenated with DDQ to get the α, α-dimethylchromenes.



CHROMENO (3′,4′:2,3)-

CHROMONE

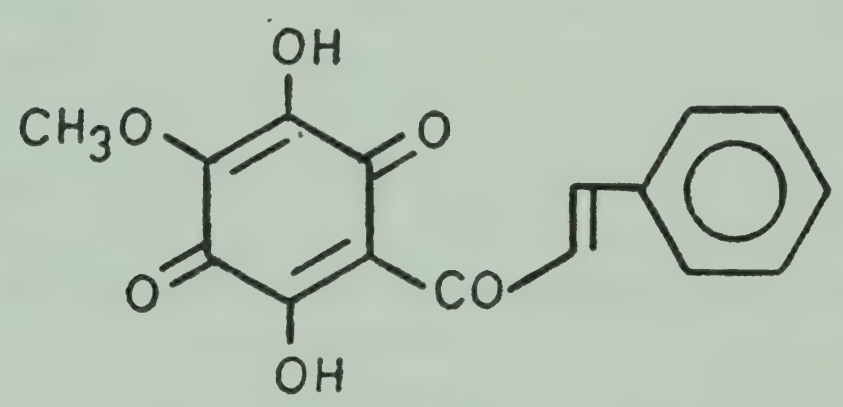
For the synthesis of the chromeno-(3′ 4′ : 2, 3)-chromone ring as is found in members of the rotenoid group, Professor Seshadri made a biogenetic approach. The highly characteristic chromeno ring was considered to be the result of dehydration between the CH_2OH group at position 2 and the OH at position 2′ of the side phenyl in a 2-hydroxymethyl-2′-hydroxy-isoflavone. A 2′-hydroxyl or methoxyl was provided, according to the circumstances of the case, either (*a*) by starting with an *o*-hydroxy or methoxy-benzoic acid or acetophenone prior to pyrone ring closure, or (*b*) by introducing the 2′ -OH in the finished flavone by *p*-oxidation. Providing the CH_2OH group at the 2-position was slightly more involved. Attempts were first made to convert the reactive CH_3 group at position 2 into CH_2OH. This was achieved by the action of N-bromosuccinimide (in the presence of benzoyl peroxide) on the acetate of the parent compound. The bromine was then replaced by OH by boiling with dilute, hydrochloric acid. Elimination of water between the 2-CH_2OH and 2′-OH groups was easily achieved by boiling an acetone soluttion of the compound with anhydrous potassium carbonate. The product was the required chromeno-chromone.

Study of Some Indian Medicinal Plants

Butea frondosa– This Indian medicinal plant has been the subject of investigation in several laboratories. Perkin isolated the aglycone butin (7, 3′, 4′-trihydroxy-flavanone). Lal and Dutt isolated a glycoside called butrin which they considered to

contain two glucose units present as a biose attached to the aglucone. Seshadri and coworkers established the correct structure of butrin as 7,3′-di-*o*-glucosylbutin. They also isolated and established the structure of the chalkone corresponding to the free aglycone, viz.,3, 4, 2′, 4′-tetra-hydroxy-chalkone called butein (1) and the 3, 4′-di-*o*-glucoside of butein called isobutrin. A coumarone glycoside called palasitrin also from the same plant source was shown to be 2-(3-glucosyloxy-4-hydroxy benzylidine)-6-glucosyloxy-coumaran-3-one. It was thus related to isobutrin having the sugars in the same position but it was a benzylidene coumaranone instead of a chalkone. It was, therefore, an easy step to convert isobutrin into palasitrin. This was effected by acetylating isobutrin, making its dibromide and treating it with alcoholic potash whereby ring closure to coumaranone and deacetylation took place yielding palasitrin.

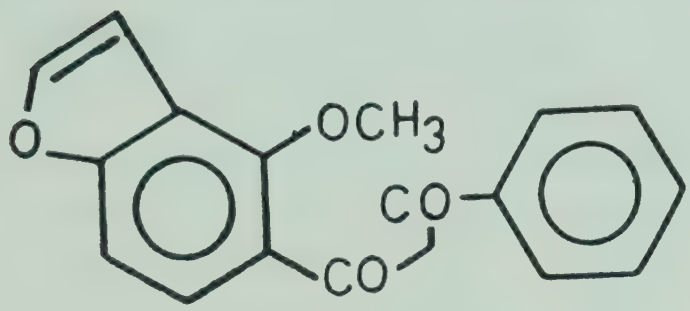
Didymocarpus pedicellata—From the leaves of this medicinal plants Siddiqui first isolated pedicellin which was shown to be 2′,3′,4′,5′,6′-pentamethoxy chalkone. The structure proposed by Siddiqui for the dihydroxy-trimethoxy chalkone pedicine was revised by Seshadri to 2′,5′-dihydroxy-3′,4′,6′-trimethoxy chalkone. Usual ring closure of this chalkone yielded the flavanone called isopedicine (6-hydroxy-5, 7,8-trimethoxy-flavanone). Mild oxidation of pedicine with benzoquinone or silver oxide yielded the 2′ 6′-quinone(quinochalkone). Of the three methoxyls (at 3′,4′ and 6′-positions) in this quinochalkone those at 3′ and 6′ positions could be hydrolysed to hydroxyl by mild treatment with sodium hydroxide yielding the dihydroxy mono-methoxy-quinochalkone, pedicinin, while only the methoxyl at 6′ position was hydrolysed with sodium bicarbonate yielding the monohydroxy- dimethoxy-quinochalkone, methylpedicinin.



PEDICININ

While on the topic of *D. pedicellata* it may be mentioned that a succinic acid derivation has also been isolated from the leaves and named pedicellic acid. Its structure has been established as 2-methyl-3-tridecyl-succinic acid.

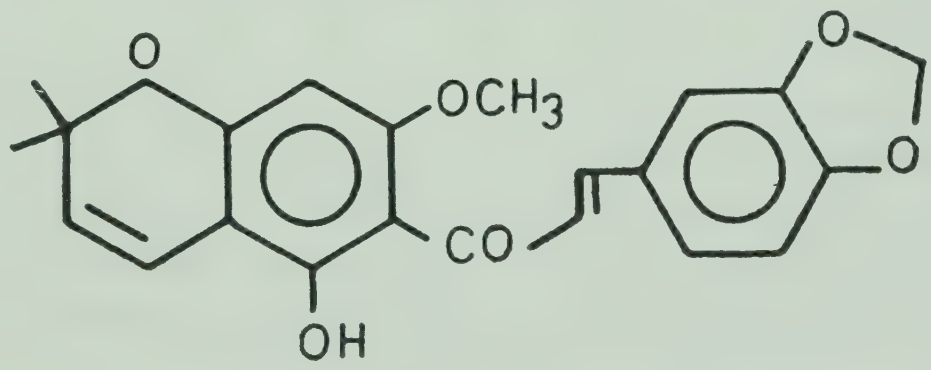
Carthamus tinctorius—The flowers of this plant were examined by Professor Perkin as early as 1918. Seshadri provided new methods for the synthesis of the aglycone carthamidin (5′,7′,8′,4′-tetrahydroxy-flavanone) and its isomer isocarthamidin (5,6,7,4′-tetrahydroxy-flavanone). The yellow substance called carthamin was shown to be 4,3′,4′,6′-tetrahydroxy 2′-glucosyloxy-chalkone, the red principle carthamone to be the corresponding 3′, 6′-quinochalkone with the glucosyloxy and other hydroxyls in the same position and another colourless accompanying substance neo-carthamin to be the corresponding flavanone viz. 5-glucosyloxy-6,7,4′-trihydroxy-flavanone.



PONGAMOL

Prunus puddum — The first natural isoflavanone to be isolated by Seshadri & coworkers was padmakastein (5,4′-di-hydroxy-7-methoxy-isoflavanone) from the bark of *Prunus puddum*, together with padmakastin which is its glucoside. Padmakastein derivatives are dehydrogenated with SeO_2 to prunetin isoflavone) derivatives and the converse is achieved by hydrogenation in the presence of palladium carbon.

Pongamia glabra—This is an important plant in Indian folk medicine. From its seed oil, a substance called karanjin was isolated and its structure established by Professor Spath as 3-methoxy-furano-(2′,3′,7,8) flavone in the 1930's. Later investigations have all come from Seshadri's laboratories. Other components isolated from the seed are kanjone (6-methoxy-furano-(2′,3′,7,8)-flavone) , pongapin (3-methoxy-3′,4′-methyl-enedioxy-furano-(2″,3″,7,8)-flavone) and the corresponding 3-demethoxy compound called ponga-glabrone and a β-diketone called pongamol (1-2-methoxy furano-(2′,3′,$_5$4,3)-phenyl-3-phenyl propane-1,3, dione). The roots and stem bark contained kanugin (3,7,5′-trimethoxy 3′,4′-methylenedioxy flavone), demethoxykanugin(the 5′-demethoxy compound) and pongachromene a chromenoflavone (3-methoxy-3′, 4′-methylenedioxy 6″, 6″ dimethylpyrano-(2″,3″,7,8)-flavone). The leaves contain the chromeno-chalkone called glabrachromene which is 2,2-dimethyl-5-hydroxy-7-methoxy-chrom-3-ene with a 3,4-methylenedioxycinnamoyl residue at position 6. A minor compound recently isolated from the leaves is 3′-methoxypongapin.



GLABRACHROMENE

A compound belonging to an entirely different chemical group which was obtained also from the seeds is glabrin. Its structure remined unresolved for three decades until high resolution mass spectrometry led to its structure as 4,5-dihydroxy-N-methyl-piperidine-2-carboxylic acid.

Psoralea corylifolia—The seeds of this plant constitute a well-known drug in Indian medicine. Its active principles, psoralen and isopsoralen (angelicin) were studied by Professor Spath in the thirties and shown to be linear (7,6) and

angular (7,8) furocoumarin respectively. A revival of interest in this drug during the fifties led to new methods of synthesis and to the isolation of new substances from it. Following a biogenetic pathway, 6-C-prenyl- or 6-allyl-7-hydroxy-coumarin was ozonolysed by Seshadri and coworkers and the resulting 6-acetaldehyde ring-closed (PPA has been found to be a very good condensing agent) to give psoralen. Isopsoralen (angelicin) was similarly synthesised from the 8-allyl-7-hydroxy coumarin. New compounds isolated from the drug are bavachin (6-prenyl-7,4'-dihydroxy-flavanone) and isobavachin(its 8-prenyl isomer), the chalkone(4,2′,4′-trihydroxy-5′-prenyl-chalkone) corresponding to bavachin called bavanchalkone, and the analogous isobavachalkone (3′-prenyl compound). They have all been synthesised. When the prenyl residue in bavach*al*kone closes up the ring with the hydroxyl ortho to it, it results in the chalkone α,α-dimethylchroman which can be dehydrogenated to the chromene which also occurs in the seed and has been named bavachromene. A new isoflavone called neobava-isoflavone has also been isolated from the seeds and shown to be 3′-prenyl-7,4′-dihydroxy-isoflavone.

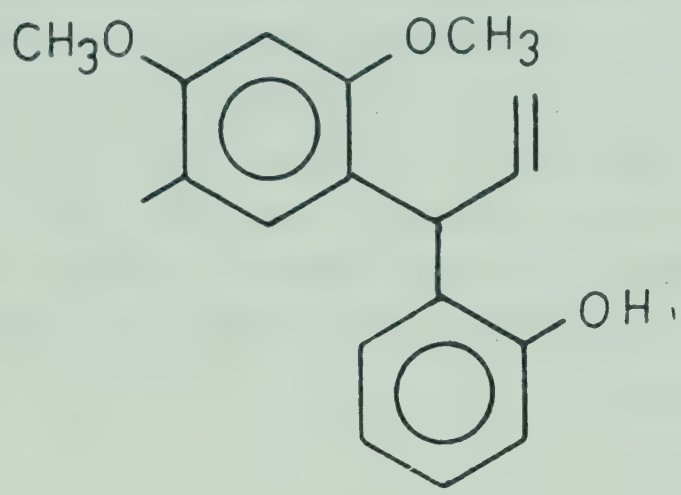
Gossypol—Gossypol, the golden yellow colouring matter of cotton seed and its oil have been studied in the USA, India and USSR. The gross structure of the molecule was established by Professor Roger Adams of USA as a symmetrically substituted 2,2′-binaphthyl with hydroxyls at 1,6 and 7 positions, formyl at 8, a methyl at 3 and an isopropyl at 5, in each half of the molecule. Seshadri worked out a convenient method for obtaining gossypol from cotton seed oil be precipitating the sparingly soluble anil and heating it with acetic anhydride whereby gossypol hexacetate is obtained. Confirmatory evidence for the *o*-hydroxy-aldehyde grouping in gossypol was provided by Seshadri by utilising this structural feature to build up α-pyrones and flavylium salts.

During his work relating to Gossypol, Professor Adams had observed that Gossypol and its derivatives like the hexamethyl ether and the hexa-acetate did not show constant melting point or crystal form. This is due to the fact that the hydroxyl at 1 and the formyl at 8 position in gossypol can ring-close to form a lactol and this can happen in one or both rings. Further, at each lactol carbon, two configurations are possible. Professor Seshadri succeeded in isolating all the six methyl ethers and two acetates in pure form.

Another important aspect of gossypol studies is the optical activity of the parent substance and its derivatives. Much light on this was shed by the study of gossypol isolated from *Thespasia populnea*, another plant of the family Malvaceae. Professor Seshadri prepared apo ad des-apo gossypol in optically active forms from (+) gossypol, proving thereby the presence of atropo-isomerism in gossypol and its derivatives.

Neoflavonoids

The term neoflavonoids was introduced into the literature during the sixties to denote 4-phenylcoumarins and related compounds which comprise mainly the following groups : dalbergins, dalbergiquinols, dalbergiquinones, 4-phenyl-3-chromenes and brazilins (4-phenylchromans with a methylene bridge connecting position 3 and 2′). Professor Seshadri has contributed much to the first four groups. The name dalbergin was given to a substance first isolated, from the heart wood of

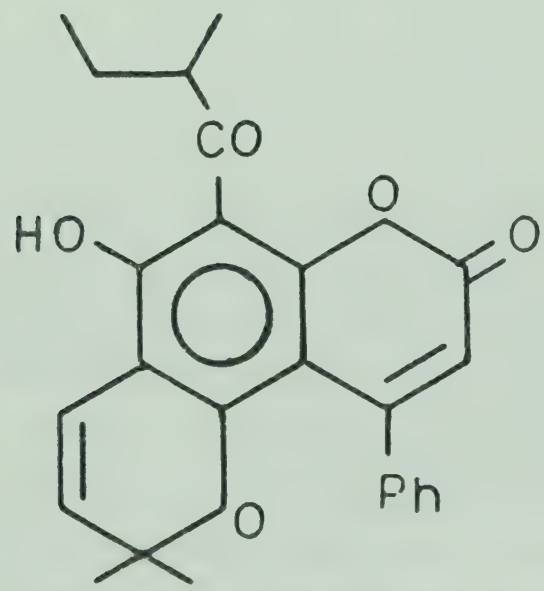


LATIFOLIN

Dalbergia sissoo and its structure was elucidated as 6-hydroxy-7-methoxy-4-phenyl-coumarin. Related compounds isolated from *D. sissoo* are the 6,7-dimethoxy-6, 7-dihydroxy- and 6-methoxy-7-hydroxy-4-phenyl-coumarins; these have been given trivial names showing their relationship to dalbergin. From *D. latifolia* a substance called latifolin was isolated whose structure was elucidated as 2,4-dimethoxy-5-hydroxyphenyl-2′-hydroxy phenyl-vinyl-methane. It can also be looked upon as a 1 : 4-quinol-1-methyl ether with a benzyl side chain in position 2 and other groups in other positions, and the parent quinol itself has been designated as a dalbergiquinol. Since it has an asymmetric carbon it is optically active and the configuration has been elucidated as R.

A compound named Dalbergichromene (6-hydroxy-7-methoxy-4-phenyl-3-chromene) has been isolated from the heart wood of *D. sissoo*. It has been synthesised by reductive ring opening of dalbergin with LAH and cyclodehydration of the resulting *o*-hydroxy-cinnamyl alcohol with acidic reagents (Amberlite IR-120 H^+ form has been found very efficient). Dalbergichromene also results from dalbergiquinone by allowing it to undergo isomerisation with hot pyridine.

Professor Seshadri has suggested a scheme for the biogenesis of these groups of compounds which is largely akin to the above laboratory methods. Union of a C6 and C9 unit, which by C-acylation gives rise to chalkone and therefrom to flavonoids



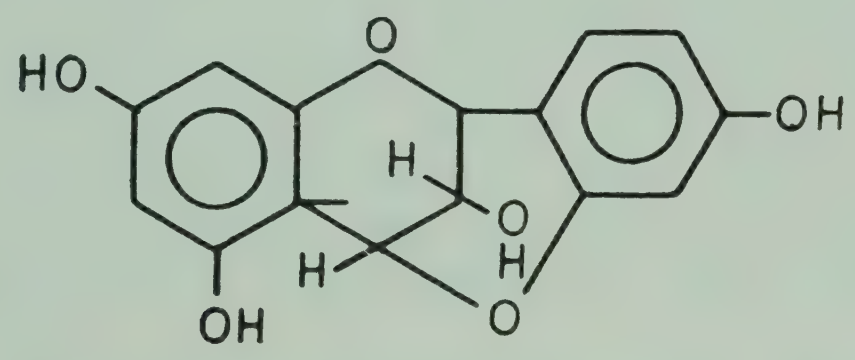
PONNALIDE

and isoflavonoids, will, by O-acylation, give rise to cinnamic esters of phenols, whose ring closure will give rise to 4-phenylcoumarins from which dalbergiquinols, dalbergiquinones and 4-phenyl-3-chromenes are easily obtainable.

A 4-phenylcoumarin obtained by Seshadri and co-workers from the tropical medicinal tree *Calophylum inophyllum* is ponnalide, which, can be represented as a 7-hydroxy-4-phenyl-coumarin with an α-methyl-butyroyl side chain at position 8 and 8 and a 2′, 2′-dimethyl-chromene ring fused to 5,6-positions constituting a chromeno-(6′5′ : 5,6)-coumarin.

Cyanomaclurin

Cyanomaclurin is the chief constituent of the Indian Jack fruit tree (*Arto-carpus heterophyllus*). It was recognised long ago as a leucoanthocyanidin derivative by Professor Robinson, who gave it a hemiketal structure. The correct structure was arrived at one the basis of NMR studies by Professor Seshadri and his group and by

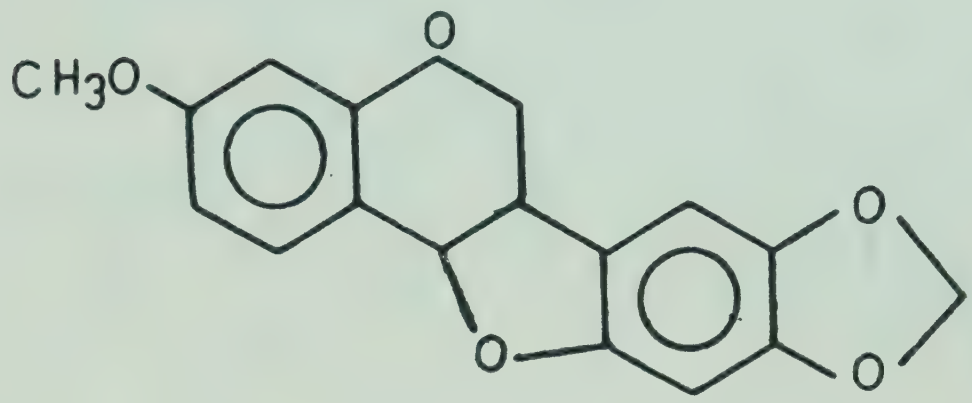


CYANOMACLURIN

Professor Venkataraman and his group and it is now known to be 4, 2′-oxido-3,5,7, 4′-tetrahydroxyflavan. This structure was supported by the synthesis of related structures and finally of cyanomaclurin trimethyl ether. For this 2 -benzyloxy-5,7, 4′-trimethoxyflavanone was oxidised with alkaline hydrogen peroxide to give the flavanone-3-ol. Catalytic debenzylation liberated the 2′-hydroxyl. Sodium borohydride reduced the carbonyl at 4 and under the influence of acidic reagents the 4-OH reacted with the 2′-OH eliminating water and yielded cyanomaclurin trimethyl ether.

Pterocarpans

Pterocarpans have become a sizeable group in recent decades. They have been obtained mostly from the heart woods of trees such as red sanders (*Pterocarpus santalinus*) and their structures have been deduced mainly from spectral studies. Though the first members of this group viz., pterocarpin and homopterocarpin were isolated more than a hundred years ago and their constitutions established in 1940, their synthesis had to wait till recently due to non-availability of the necessary synthetic procedures. The essential laboratory precursor is the appropriate 2′-hydroxyisoflavone. Borohydride treatment led to the reduction of the CO (position 4) to CHOH, and simultaneous reduction of the 2,3-double bond, giving isoflavan-4-ol. Treatment of the product with HCL in the course of work-up led to spontaneous



PTEROCARPIN

cyclisation involving dehydration between the hydroxyls at 4 and 2′-positions, resulting in the pterocarpan skeleton. Employing this method a number of variously substituted pterocarpans were synthesised including a racemate of homopterocarpin.

Biflavonyls

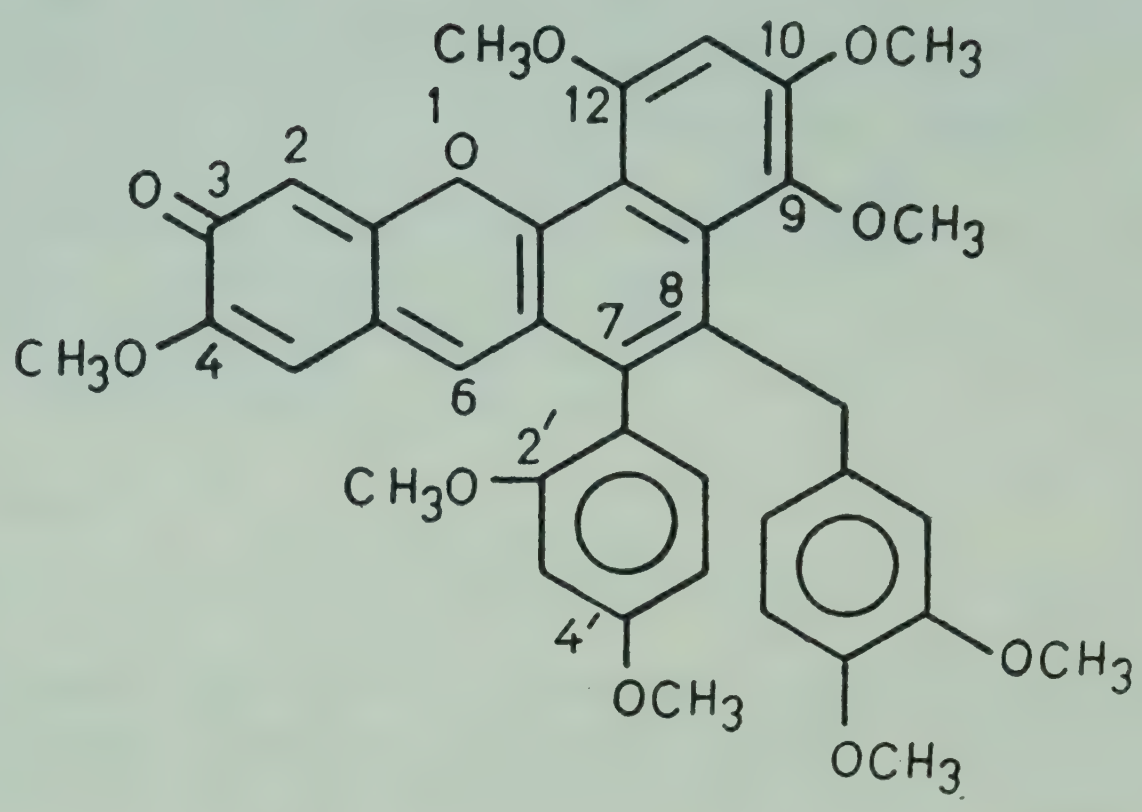
These are compounds discovered during the sixties and their structure determination is beset with several difficulties that were tackled skilfully by Seshadri and coworkers. From *Cupressus torulosa,* a compound called cupressuflavone was isolated and its structure established as a biapigeninyl. The linkage between the two flavone units could be settled satisfactorily only by approaching the problem from several angles and by comparison with model substances, synthetically prepared. For linking up the two halves of the molecule Ullmann's reaction has been the method of choice. Mass and NMR spectral methods have shed much light on the problem and cupressuflavone is now accepted to have the structure 8,8-biapigeninyl. Some other Indian plants of the Cupressaceae family have also been screened for their biflavonyl contents.

Santalin pigments

The red pigment obtained from the heart wood of the forest tree *Pterocarpus santalinus* and called santalin which formed the subject matter of early investigations in British laboratories, has now been found to be a mixture, having two major components which have been given the names santalin-A and santalin-B. Both of them have methoxyl and phenolic groups and both give the same permethyl ether, and this has been subjected to extensive degradative studies. Based on the chemical identity of the degradation products the structure of the permethyl ether, which has eight methoxy groups, has been worked out by Seshadri and coworkers. This structure is quite close to the currently accepted structure and incorporates the correct nucleus.

Bicoumarinyl

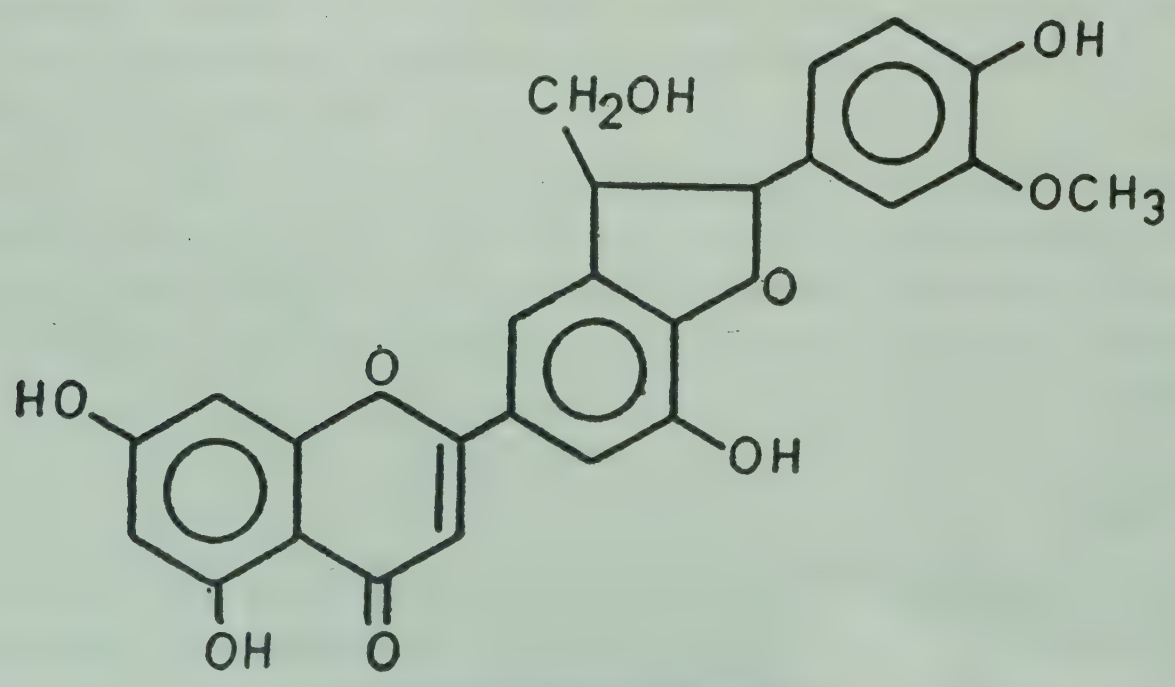
A substance designated as candicanin isolated from the roots of *Heracleum candicans* was shown to have a novel type of bicoumarimyl structure as tertiary O-imperatorinyl-heraclenol by Seshadri and his school.



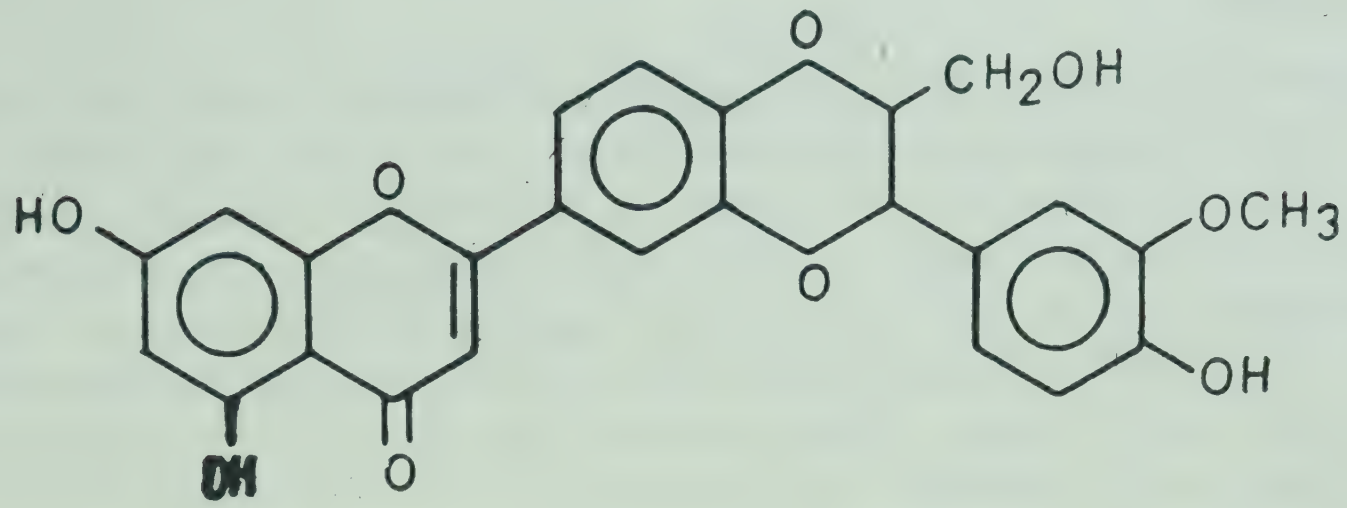
PER-O-METHYL SANTALIN

Flavonolignans

Flavonolignans are a new group of compounds consisting of a combination of a C15 (flavonoid) and C9 unit, the latter being linked to the side phenyl of the former. The first known member is silybin isolated and studied in Professor Wagner's laboratory in Munich, and is constituted from taxifolin to which the *alfa* and *beta* carbon atoms of 3-methoxy-4-hydroxy-phenyl-propanol are linked to the 4′-0 and 3′-0 respectively of taxifolin thereby constituting a new dioxane ring. From the seeds hulls of *Hydnocarpus wightiana* Seshadri and Ranganathan isolated a new substance called hydrocarpin which was studied elaborately and shown to be constituted in the same manner as silybin, with the difference that it was derived from luteolin instead of taxifolin. The same material also yielded an isomeric substance called isohydnocarpin which has a dihydrofuran rings as shown. Isohydnocarpin thus bears the same relationship to hydrocarpin that silycristin of Professor Wagner does to silybin. A third flavonolignan isolated from theseed hulls of *H. wightiana* was shown to be a methoxyhydnocarpin.



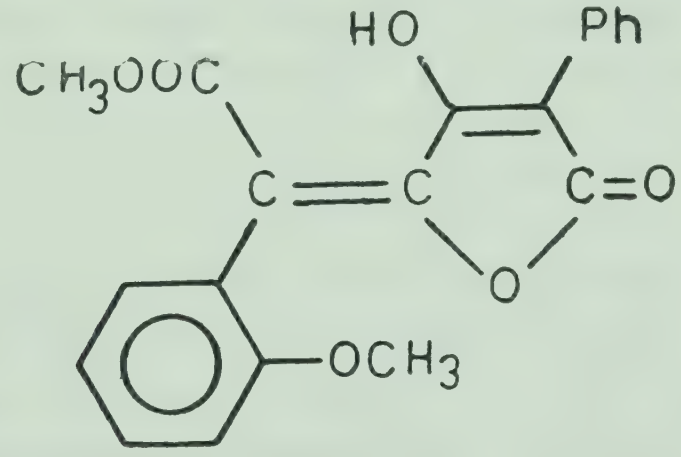
ISOHYDNOCARPIN



HYDNOCARPIN

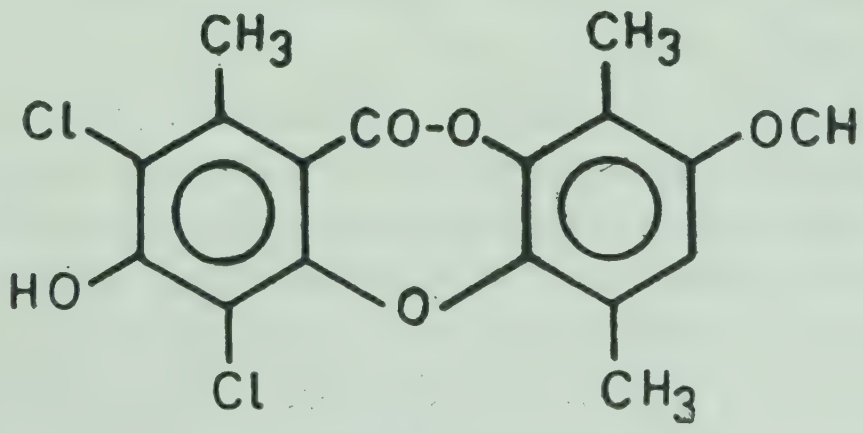
Lichen substances

Lichens are interesting plant organisms being symbionts of algae and fungi. Investigations of the components of lichens on the one hand and fungal products on the other have shown that the characteristic lichen substances are really the metabolic products of the fungi. Seshadri was a pioneer of lichen studies in India and one of the leading lichen chemists in the world. His investigations of lichens which began in the thirties when he was in the Andhra University and covered lichens growing in South India, Sri Lanka and some countries of South-east Asia were extended to lichens of the Himalayas after he moved to the Delhi University. Several new compounds were discovered, their structure established and synthesis



LEPRAPINIC ACID

effected in most cases. Mention may be made of *montagnetol, erythrin, teloschistin, virensic acid, pyxiferin, pinastric acid, leprapinic acid, vicanicin and retigeradiol.*

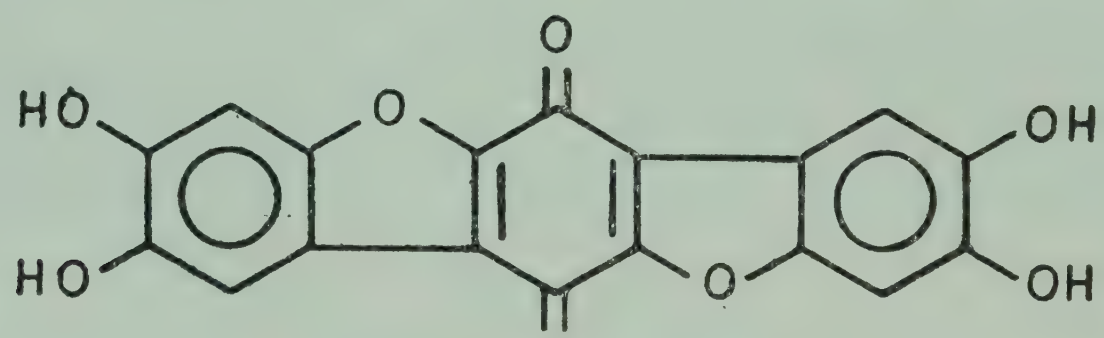


VICANICIN

C-Glycosides

The first C-glycoside to be investigated by the Seshadri school was mangiferin isolated from the mango tree (*Mangifera indica*) and some other plants. It was shown to be 2-C-β-D-glucopyranosyl-1,3,6,7-tetrahydroxyxanthone, and it was synthesised by C-glucosylating 1,3,6,7-tetrahydroxyxanthone with tetra-acetyl-α-D-glucopyranosyl bromide, the sugar residue entering the most reactive 2-position. Two new C-glycosides isolated from the leaves of *Parkinsonia aculeata* and named parkinsonin-A and -B were shown to be β-C-glucoside of 5-0-methylluteolin with stereochemistry as in orientin and 8-C-glucoside of 5,7-di-O-methylluteolin with stereochemistry as in epi-orientin.

From *Pueraria tuberosa* the di-acetata of puerarin (8-C-β-D-glucopyranosyl-4′, 7-dihydroxy-isoflavone) was isolated. Paniculatin from the bark of *Dalbergia paniculata* was assigned the structure 6,8-di-C-glucosyl-genistein. Volubilin and iso-volubilin from the flowers of *Dalbergia volubilis* were shown to be respectively 8-C- and 6-C-L-ribopyranosyl-4′, 7-di-O-methyl-genistein. From the seeds of *Trigonella corniculata* 6,8-di-C-β-glucopyranosyl-4′-O-methyl-apigenin and its mono-acetate were obtained and their structures established.

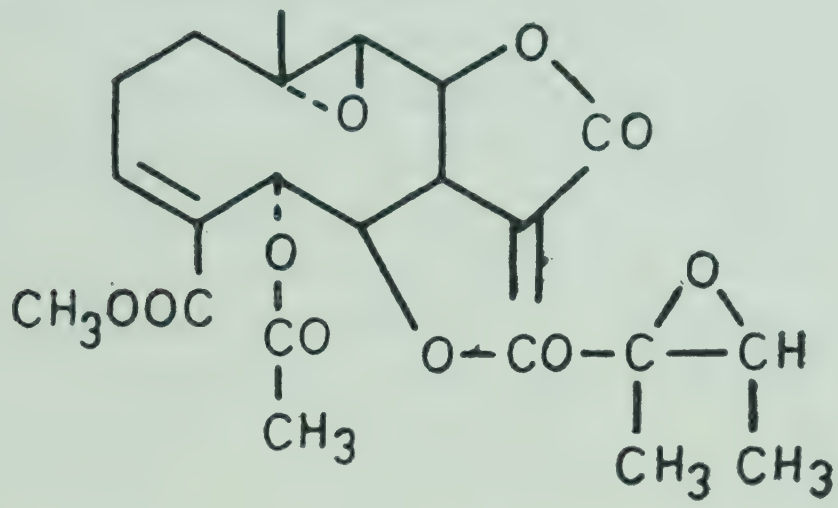


THELEPHORIC ACID

Thelephoric acid, an earlier known compound was isolated from *Labaria isidosa* and its earlier incorrect structure was corrected to that of a symmetrical terphenyl quinone. It is a 2,5-diphenyl-1, 4-benzoaquinone with an oxide bridge between 3 and 2′ and also between 6 and 2″ positions forming two furan rings, and with four free hydroxyls at 4′,5′,4″ and 5″ positions.

Terpenoids

Some amount of work an sesquiterpenes, diterpenes, triterpenes and polyterpenes was natural in the course of work on a range of natural materials. Substances of the sequiterpene group present in *Pterocarpus santalinus* have been mentioned elsewhere. Diterpenes figured in the work on *Croton oblongifolius*. Oblongifoliol and desoxyoblongifoliol have been assigned the structure entisopimara-7, 15-diene-3β, 19-diol and its 19-deoxy derivative, and the 19-carboxylic acid is oblongifolic acid. 11-Dehydrohardwickic acid is a new diterpene obtained from the same plant. (16 *alfa*-Hydroxykauran-19-oic acid was isolated from *Enhydra fluctuans* and its structure established). Enhydrin, another compound isolated from *E. fluctuans* has been shown to be a new germacranolide with two epoxy rings. Two triterpenic seco-acids, putrolic acid and putric acid and two neutral compounds putrone and



ENHYDRIN

putrol were isolated from *Putranjiva roxburghii* and their structures correlated with that of friedelin. Candicopimaric acid from *Heracleum candicans* was related to pimaric acid. Work on retigeradiol has been mentioned under lichens.

Theories of Biogenesis

The activities of the research school of Seshadri resulted in the isolation and structure study of a very large number of compounds. When the data that had thus become available were codified, it was but natural to speculate on the inter-relationships between them. Seshadri thus became interested in the possible mode of biogenesis of each group of compounds that he came across and proposed theories which were subsequently corroborated by synthetical work employing tracer techniques in his own laboratories, and in laboratories in other parts of the world.

The early speculations regarding anthoxanthins were an extension of Professor Robinson's theory of the parallel origin of the anthoxanthins from a common precursor derived from a C6 and a C9 unit, and involved ideas of sequential evolution by processes of nuclear oxidation, nuclear reduction and nuclear methylation. Schemes have also been suggested for the biogenesis of anthocyanins and of other classes of natural products like lichen depsides and depsidones, xanthones, different types of quinones like benzoquinones, naphthoquinones including binaphthyls like gossypol and perylene quinones, and anthraquinones, and mould metabolites. In all these the orsellinic acid C8 unit has been assigned a key role.

Other groups about whose origin Seshadiri speculated are naturally occurring tetronic acid derivatives, 3- and 4-phenylchromans and benzophenones' stilbenes and phenylisocoumarins, the C5 unit in plants, pulvinic acid derivatives and mould tropolones. Last came the speculations on neoflavonoids and a revised biogenesis of xanthones in Guttifearae according to which the xanthone arises from a 5-hydroxy 4-phenylcoumarin. This undergoes oxidative cyclisation between the 5-OH and 2′-position, and this is followed by ring opening and elimination of C2 and C3 of the coumarin ring. The result is a xanthone. The substitution patterns observed in natural xanthones seem to support this view of biogenesis, and the theoretical reasoning has received confirmation through laboratory synthesis.

Honours and Distinctions

The scientific community in India honoured him in several ways. He was Cooch-Behar Professor of the Indian Association for the Cultivation of Science, Calcutta, Professor H. K. Sen Lecturer of the Instiution of Chemists, India, Professor B. C. Guha Lecturer of the Indian Science Congress Association, Professor B. K. Singh Lecturer of the Panjab University and Professor K. Venkataraman Lecturer of the Bombay University. He held Honorary Professorships at the Universities of Andhra and Osmania and received the Honorary Doctorate degrees of the Universities of Andhra, Banaras, Delhi and Osmania. He was Chairman of the Indian National Committee for Chemistry and Chairman of the Panel for Chemistry and Biology under the Indo-Soviet Agreement on Scientific and Technical Cooperation. He was the leader of the Indian delegation to the First and Second Indo-Soviet Symposium on the *Chemistry of Natural Products,* held in 1968 and 1970, and Chairman of the *8th International Symposium on the Chemistry of Natural Products* held at Delhi in 1972. He was President of the Indian Chemical Society, of the Indian Pharmaceutical Association and of the Oil Technologists Association of India. He was Chairman of the North Indian Section of the Royal Institute of Chemistry. He was President of the Indian Pharmaceutical Congress, General President of the Indian Science Congress (I966–67) and President of the Indian National Science Academy (formerly called the National Institute of Sciences of India) (1967–68). He was Vice-President of the Indian Academy of Sciences, Bangalore of which Sir C. V. Raman was the President. He received two medals from the Indian Chemical Society, the *Acharya Prafulla Chandra Ray Medal* and the *Acharya Jananendra Ghosh Medal,* and two medals from the Indian National Science Academy, the *Shanti Swarup Bhatnagar Medal* and *Meghnad Saha Medal.* He was one of the three Honorary Members of the Indian Science Congress Association elected on the occasion of its Silver Jubilee and he was an Honorary Fellow the Deutsche Akademie Naturforscher Leopaldina. He was Adviser to the London Chemical Society for India. In 1963, the President of India honoured him by conferring the title of *Padma Bhushan* for his distinguished services to science and public life in India.

Professor Seshadri had great affection for his students and helped them in all possible ways. He initiated them into research, guided them in their day-to-day research problems, helped them to write up research papers and theses, gave them training to express themselves lucidly before critical audiences, encouraged them to develop into capable leaders of science and even helped them financially whenever a need arose. He also helped them secure suitable positions in life. It was, therefore, not unusual that they celebrated his 60th, 65th, 70th and 75th birthdays and his election as Fellow of the Royal Society London (FRS) in a fitting manner. They raised funds and made endowments to the Andhra and Delhi Universities for instituting medals and prizes to mark his 60th birthday, and to the Indian National Science Academy to institute a medal to mark his 70th birthday. The first recipient of the Medal instituted in his name was Professor K. Venkataraman, a former Director of the National Chemical Laboratory, Poona and co-student of Professor Seshadri first at the Presidency College, Madras and later with Professor Robinson. On the occasion of the 60th and 75th birthdays, Professor Seshadri's students brought

out souvenirs and on the 65th and 70th birthdays they brought out two scientific publications. The 65th birthday volume was entitled, *Advancing Frontiers in the Chemistry of Natural Products* and contained nineteen reviews, contributed by his former students in their respective special areas; it was released and presented to him by Dr C. D. Deshmukh, then Vice-Chancellor of Delhi University. The 70th birthday volume entitled *Some Recent Developments in the Chemistry of Natural Products* and published by Prentice-Hall of India, contained sixteen articles contributed by eminent foreign scientists and nine articles contributed by Indian Chemists. The volume was released and presented to him by Professor D. S. Kothari, a former Chairman of the University Grants Commission.

Poignant Last Years

The last few years of Professor Seshadri's life make a sad reading. In the forties he had declined offers of positions of prestige and pelf, declaring that he would be only a University teacher. Later in 1960, he declined the offer of the Office of Chairman of the University Grants Commission. He had hoped that Chemistry would secure for him the resources to live a simple life. In 1965, he donated his personal library, the entire collection of books and journals of three decades, to the Delhi University Chemistry Department and continued to donate all the journals that he received subsequently also, hoping that he could work peacefully in the Department to the end of his life. In 1972, new rules and regulations of the Delhi University prevented him from receiving honoraria or remunerations from any quarters, thus bringing financial problems. They also came in the way of running research projects, thus cutting off all sources of research scholarships and funds for meeting research expenses. None could register with him for the Ph.D degree, and since in India no young graduate wants to do research unless he can get a Ph.D degree, all prospective students got diverted. He was without research grants and without means of subsistence. This was a great disappointment to him and affected him deeply, in spite of his moral courage and spiritual strength. In 1973, he had a second heart attack and in 1974, it was diagnosed he had gastric ulcer. A remarkable recovery followed and every thing looked bright till in September 1975 when it was discovered that something had gone seriously wrong. The gastric pain became acute and he vomitted blood repeatedly. The ulcer had turned malignant. He was rushed to hospital on the night of September 17. He was operated upon but his heart failed on the morning of September 27, 1975.

Thus ended the life of a great son of India who was rated by his compeers as one of the most eminent, most dedicated and most fearless among the scientists of the country, and a singular example of simplicity and humility. Professor Seshadri's passion for truth and rectitude was so great that he could never compromise on matters of profound importance for the welfare of society and the country. He never towed the path of worldly success by agreeing with others simply because they were powerful or belonged to influential, scientific or political groups. He was an unrelenting critic wherever things went wrong. The consequence was tragic and is best described by quoting from the 14th Founder Memorial Lecture (1978) of the Sri Ram Institute for Industrial Research, Delhi, delivered by Dr Atma Ram :

"Every scientist, however eminent, must be prepared to suffer the consequence of his individuality of opinions however scientifically correct they may be, if he does not fall in line with one or the other of the scientific groups or the political and bureaucratic power. We have in India the example of a scienist like T. R. Seshadri, who could not see eye to eye with the governmental scientific organisations in their manner of functioning, and was critical of the politician's interference and overlordship over scientific bodies, being singularly isolated to the extent that he had to undergo considerable suffering and die in penury."

Such was the poignancy felt by Dr Atma Ram and by many others over the neglect of this great scientist towards the end of his life. The author of the memoir came under the influence of Dr Seshadri in 1935, joined his research group in 1936, grew under him, looked upon him as his mentor, and, in a sort of rare and unconventional personal relationship, was a witness to all his glory and all his tragedies.

Professor Seshadri was survived by his wife and three daughters.

S. RANGASWAMI

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KSHITISH CHANDRA SEN

(1899–1977)

Elected F.N.I. 1949

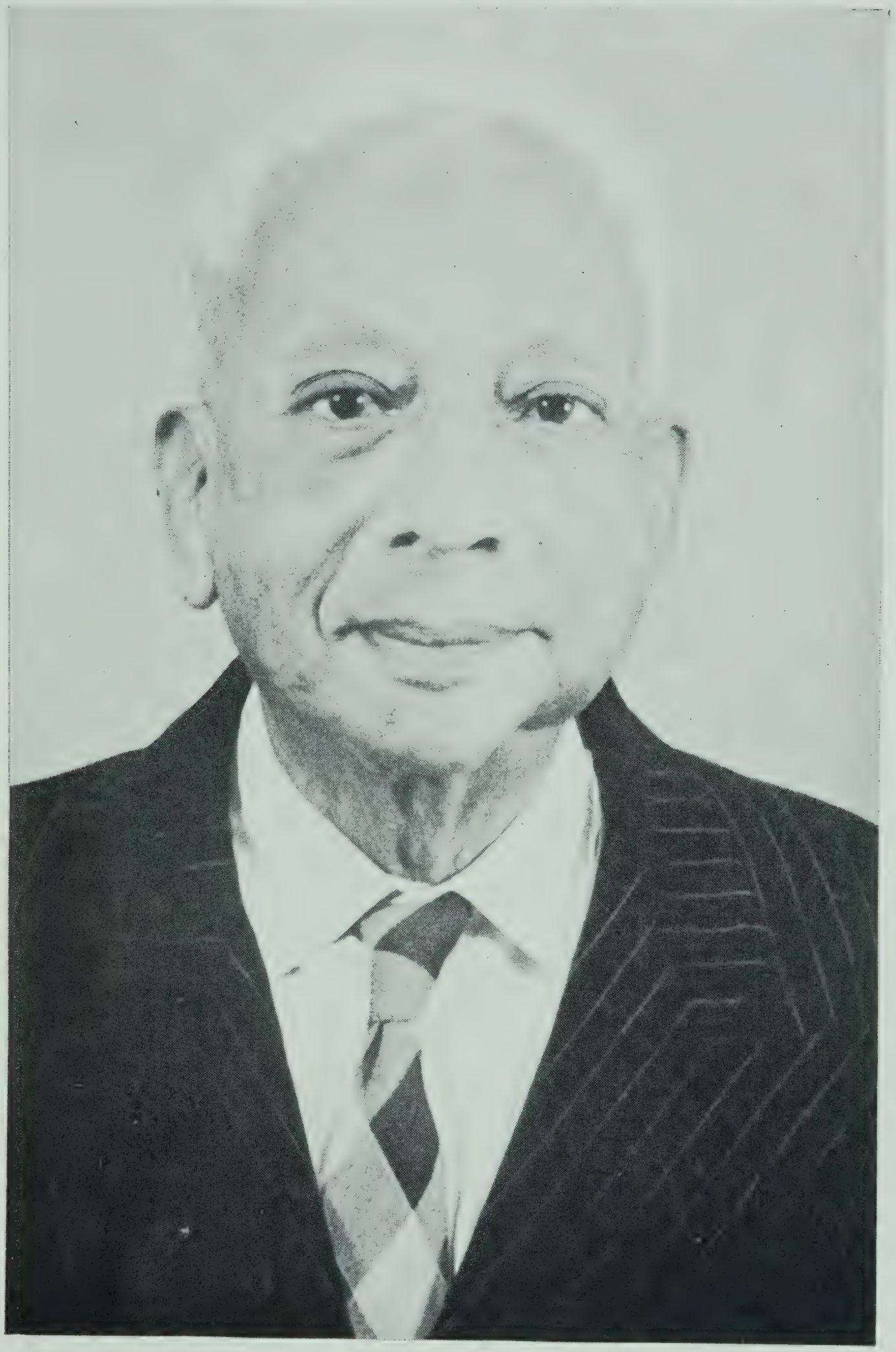
KSHITISH CHANDRA SEN was born on September 5, 1899, in Khulna in the former Bengal Presidency. His father, Shri Ambica Charan Sen and his mother, Srimati Saramala Sen, had four sons, Kshitish being the third. His second brother, Dr Satish Chandra Sen, was a distinguished radiologist and Past-President of the Indian Medical Association. Dr K. C. Sen was a bachelor. He passed away in the early hours of February 27, 1977.

EARLY LIFE AND EDUCATION

Dr Sen had his primary and secondary education in the Government High School, Jessore (now in Bangladesh). He matriculated from the Calcutta University in 1915 and was placed in the First Division. He then joined the Bangabasi College at Calcutta and passed Intermediate in Science in 1917. At this stage, fate played a part which was responsible in shaping his ultimate career. He was admitted to the Medical College, Calcutta, but could not join the classes as he was interned for a year for alleged revolutionary activities. His internship was lifted in 1918, but then it was not possible for him to rejoin the Medical College. He was thus forced to go back to the Bangabasi College, from where he passed the Bachelor of Science examination in 1920 with distinction. He then, joined the Allahabad University and took the Master of Science degree in Chemistry in 1922. He continued post-graduate research in physical chemistry in the same university under the guidance of Professor N. R. Dhar and obtained the D.Sc. degree in 1925.

PROFESSIONAL CAREER

Dr Sen started his career as a Demonstrator in Chemistry at the University of Allahabad in 1924. In 1929, he was appointed to the newly created post of Biochemist in the Imperial Veterinary Research Institute, Mukteshwar-Kumaun (Government of India). In 1931, he did research in the Biochemistry Laboratory, Cambridge and Rowett Research Institute, Aberdeen. In 1936, after the reorganisation of the Imperial Veterinary Research Institute, when a new Section (later Division) of Animal Nutrition Research was formed, Dr Sen was selected to become its first Head. Under his leadership, animal nutrition research flourished and this centre received international recognition. He and his coworkers made important studies on the



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role of nutrition and the quality of milk and milk products. These received recognition by his appointment in 1944 as the Director of Dairy Research in the Indian Dairy Research Institute at Bangalore. Later, through his efforts, the National Dairy Research Institute was established in Karnal, Haryana, which became one of the premier research institutions under the Indian Council of Agricultural Research.

Dr Sen retired from Government service in September, 1957.

Scientific Contributions

At the University of Allahabad, Dr Sen worked mainly in the field of colloid chemistry. On the basis of his studies on adsorption, he put forward a new interpretation of Schulze-Hardy Law. This paper, published in the *Journal of Physical Chemistry* in 1924, was acclaimed widely. Later, on the basis of his work on the stability of different colloidal solutions, he developed a general theory of ion antagonism. From 1928, he became interested in the problem of haemolysis, and published many papers in this field.

He joined the Imperial Veterinary Research Institute in 1929 and directed his activity to nutritional problems of Indian livestock. He drew attention to the part played by malnutrition, particularly to mineral deficiencies and imbalance, on the incidence of several diseases and unthriftiness among Indian farm animals. Later on, at the Animal Nutrition Division, Izatnagar, he and his coworkers found that the negative balance in calcium in cattle, caused by feeding them rice straw, was mainly due to the alkalosis produced through ingestion of large quantities of oxalates present in that roughage. Washing with water and treatment with dilute alkali were found effective in removing most of the oxalates. Alkali-treatment thus became an accepted procedure to improve the nutritive value of straws in general and paddy straw in particular. The methods developed by Sen for analysis of mineral constituents and oxalates in biological materials are presently being used by research workers.

While the above study was in progress, Dr Sen initiated work on the carotene content of feeding stuffs. A simple technique for the estimation of β-carotene in biological materials was developed and used to study the developement, distribution and stability of β-carotene in feeding stuffs. He also investigated the effect of feeding different levels of carotene on the vitamin A potency of milk. This work was continued by him later at Bangalore, where he initiated studies on the stability of vitamin A in milk and its destruction through various milk processing procedures.

At Izatnagar, he became interested in the curious phenomenon of degeneration of draught cattle in certain parts of India. Cattle brought to the epizootic areas developed lameness after a few months and became unfit for working. After sifting all local information, Dr Sen and coworkers presumed that the syndromes were caused by fluorine intoxication. Analyses of soil and water from the affilicted areas and of the bones of the affected animals revealed abnormally high quantities of fluorine thus supporting the hypothesis of fluorosis being the cause of the pathological symptoms. Later, feeding experiments on animals given sub-toxic doses of sodium fluoride resulted in reproduction of the symptoms encountered under field conditions, only when the ration was deficient in calcium or phosphorus. As the fodders

in the epizootic areas were also found to contain sub-normal quantities of phosphorus, the field cases were diagnosed as aphosphorisis *cum* fluorosis. It was also found that the productive life of the animals could be prolonged by several years, when aluminium sulphate was given as a supplement.

As a pioneer animal nutrition research worker in India, Dr Sen was very keen on establishing the nutritional requirements of cattle under tropical conditions. At Izatnagar, he initiated work on the protein requirement of Indian cattle. This remained his main concern, even after retirement. At the First Animal Nutrition Research Workers Conference held in Trichur (Kerala) in 1966, he with the present author initiated a group discussion on suitable standards for the requirement of protein and energy for our livestock. On the basis of these discussions, it was recommended that in comparison with western standards, the protein intake of Indian cattle could safely be lowered by 10 per cent, without affecting their health and productivity. Later in 1970, at the Second Animal Nutrition Research Workers Conference at Bangalore, Dr Sen reviewed the work carried out in the energy evaluation of feeding stuffs. He expressed the view that the conventional method of expressing the energy content of feeds on the basis of Total Digestible Nutrients (TDN) overestimated the available energy values and suggested that the available energy content should be denotated in heat-units as digestible or metabolisable energy. His recommendations, with minor changes, were later adopted by the conference.

At Bangalore, Dr Sen also guided research on the effect of feeding iodinated casein on the yield and composition of milk as well as on the growth of calves. This work showed that such supplementary feeding had very little practical value.

Dr Sen and his colleagues, have published over 100 research papers. His book on *Animal Nutrition Research in India,* published by the *MacMillan & Co.* in 1953, gave an exhaustive critical review of animal nutrition work done in this country. He was also the author of a Technical Bulletin entitled *Nutritive Value of Indian Feeding stuffs and Feeding of Animals,* published by the Indian Council of Agricultural Research. The popularity of the bulletin can be gauged by the fact that since its publication in 1938, it has gone through five editions and several reprints.

Work in Committees

Dr Sen was involved with several committees, whose deliberations helped greatly in initiating and consolidating research investigations in many fields of animal nutrition and dairy science. He was Chairman of the Animal Nutrition Committee of the Indian Council of Agricultural Research for a number of years and later became Chairman of the Dairy Science Committee of that Council. Even after his retirement, he served as a member of both these committees. In these positions, he helped in initiating a number of research projects in different centres of the country.

Dr Sen was also a member of the Advisory Board and Chairman of the Nutrition Advisory Committee of the Indian Council of Medical Research. During his Chairmanship, he was instrumental in compiling a memorandum entitled *Human*

Nutrition vis-a-vis Animal Nutrition in India. This booklet focussed attention on the unbalanced nature of most human dietaries of this country. For the first time, the quantitative shortages of foods of animal origin like milk, egg and meat were calculated. Side by side, it was shown that undernutrition of Indian livestock was the main cause for deficiency in the supply of these protective foods for human consumption. It was calculated that the conventional feeding stuffs, as available under the agricultural system of this country, could supply only 40 per cent of the energy and 25 per cent of the protein requirement, if our domestic animals were to be maintained on balanced rations in order to optimize their production of protective foods for human beings. It was also pointed out in quantitative terms that given adequate inputs, the total cultivable area could be intensively exploited not only for producing sufficient food for maintaining both human and farm animal populations, but also for producing the necessary cash crops.

Dr Sen was Chairman of the Dairy Industrial Sectional Committee (AFDC 12) and member of the Animal Feeds Sectional Committee (AFDC 15) of the Indian Standards Institution from 1956 to 1967. After 1967, he continued, until his death, to be member of the newly constituted Agricultural and Food Products Committee (AFDC 15). During his service on these committees, he took a leading part in establishing the specifications of a number of animal feeds and dairy products, and also in recommending various analytical, microbiological and other related tests for various feeds and food products.

Dr Sen was the leader of the Indian delegation to the International Dairy Congress held in Rome in 1956. In 1961, he led the Indian delegation to the International Standards Organisation (Milk Products) held in West Berlin. During these trips, he took the opportunity to visit several scientific organisations and institutions in the U.S.S.R., France, Denmark, Sweden, West Germany, Holland, U.K. and U.S.A.

During 1967–68, Dr Sen acted as Chairman of the committee to evaluate the work of the *Gosamvardhana* Council of the Ministry of Food & Agriculture, Government of India. The report of this Council was helpful in adopting various measures for cattle development in India. In 1959, at the request of the Indian Council of Agricultural Research, he took up the Chairmanship of the council to evaluate the achievements of the Animal Nutrition Research Division of the Indian Veterinary Research Institute as well as the work being carried out at the Regional Animal Nutrition Research Centres at Bangalore, Haringhata (West Bengal) and Anand (Gujarat).

Dr Sen was a member of the Governing Body of the Kalyani University, (1969–70) and was the President of the Governing Body of the Bengal Veterinary College, Calcutta (1969–75).

Dr Sen was elected a Fellow of the Indian National Science Academy in 1949. He served on the Council of the Academy from 1967 to 1968. He was a Fellow of the Indian Chemical Society and also a member of the Editorial Board of the *Journal of Dairy Research,* U.K.

Indian Dairy Science Association

Dr Sen's organising abilities were remarkable. He not only built up from scratch the Animal Nutrition Division of the Indian Veterinary Research Institute,

Izatnagar but he was also the guiding spirit behind the development of the small Imperial Dairy Institute to the level of a National Institute. However, he will be best remembered for the part played by him in founding the Indian Dairy Science Association. In September 1947, he organised in Bangalore a meeting of a few persons interested in different aspects of dairying, *viz.* research, teaching, extension and administration as well as those who practised dairying as a pursuit. At that meeting, he proposed the formation of an Association with the object of bringing together all persons interested in dairying and thus the Indian Dairy Science Association was inaugurated with Dr Sen as the Founder-President. From this small beginning, thanks mainly to the vigorous start given by Dr Sen, the Association has today become one of the premier scientific associations in India. Soon after the inception of the Association, a journal entitled *Indian Journal of Dairy Science* was brought out. Dr Sen as the first editor took personal care to scrutinise meticulously all articles before they were accepted for publication. From the first issue of the journal in 1945, this patient nurturing given by Dr Sen helped to train other coworkers and future editors, under whose guidance the journal has rendered valuable service in the publication of scientific papers embodying work carried out in India and abroad. The high standard maintained by the journal for over 30 years of its existence has gained for it an international repute.

In 1947, again under the guidance of Dr Sen, another journal entitled *Indian Dairyman* was published by the Indian Dairy Science Association. This semi-popular journal received the same attention by Dr Sen. The objective of this new journal was to provide information, in non-technical language, on the results of research and on technological developments, so that they could be understood by field technicians and dairy farmers and could be gainfully applied by such persons in making dairying successful. Needless to say, the start given by Dr Sen has been ably kept up and the *Indian Dairyman* finds a place on the desk of every person in India interested in dairying.

Personal Qualities

The writer had the privilege of coming into intimate contact with Dr K. C. Sen and not only he was impressed with Dr Sen's scholarship and methodical approach to all work, but also with his vision of the future of animal sciences in India. Dr Sen fought for a rightful place for animal husbandry and dairying under the overall planning of agriculture in India. The gentle, but firm and erudite way with which he conducted all discussions left no bitter feelings. His personal magnetism drew round him a band of devoted workers, through whom he managed to leave his mark not only in the scientific field, but also in other public and private interests. Thus, after his retirement he greatly helped in the development of an area in South Calcutta known as Jodhpur Park. He took a leading part in the establishment of a Higher Secondary Girls School in that locality and was for a number of years the Chairman of its Managing Board.

In temperament, Dr Sen was urbane and courteous. He had a large stock of personal experiences which he used to narrate humourously to those who kept contact with him. In fact, in the words of poet Tagore, he had the aptitude of making

a casual acquintance his close friend. His death has left a void not only among co-workers, associates and friends, but also among Dairy Scientists in India.

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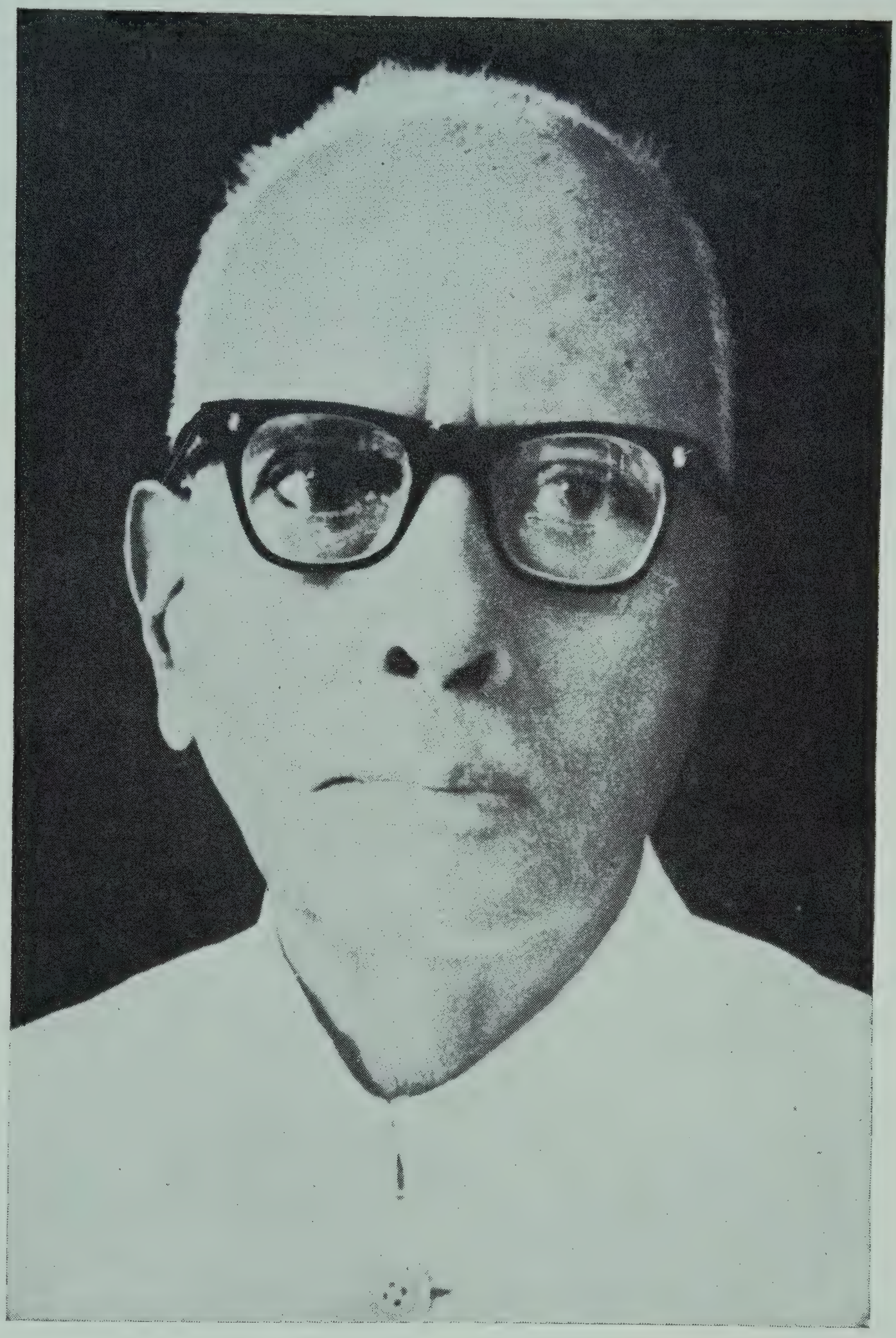

Parija

PRANAKRUSHNA PARIJA

(1891–1978)

Foundation Fellow 1935

PRANAKRUSHNA PARIJA was born on April 1, 1891 in Icchapur, a small village near Balikuda about 60 km from Cuttack in Orissa. His father, Shri Biswanath, was employed in the Forest Department in Mayurbhanj, then a princely State. It was he who infused in young Pranakrushna, a love for trees and plants. His mother, Shrimati Jayanti Devi, lavished love on her only son.

EDUCATION

Parija started his education under a village (Chatasali) school-master's supervision. It sharpened his memory, which could later help him in remembering names and details of his chosen field of study. Also ingrained in him was the high ideals of Hindu mythology and ethics. Thus, a sound base for his exalted academic career was laid right from his primary education. But for his father, he would have left studies and resigned to the keeping of land records. His father got him admitted to the Balikuda Middle English School in 1901. He completed the usual four-year course in three years, standing first in the whole of Orissa. He got a monthly stipend of Rs. 4.

Pranakrushna entered the Ravenshaw Collegiate School, appeared in the entrance examination of the Calcutta University in 1909 and stood first amongst the candidates from Orissa. It was, indeed, a rare achievement. With a monthly scholarship of Rs. 20, Pranakrushna entered Ravenshaw College, Cuttack. He stood first in the Calcutta University I.Sc. examination held in the year 1911. He then joined the Presidency College, Calcutta, for his B.Sc. and was the recipient of a monthly scholarship of Rs. 25. He had to work as a private tutor to meet his financial needs.

Parija was still an M.Sc. student in Calcutta when he was selected by the Provincial Government of Bihar for higher studies in Britain. He entered the Christ College of Cambridge University in 1914. After finishing Tripos Part I in 1916, he studied Botany under the world renowned Professors Steward and Blackman in Tripos Part II and passed the latter examination securing a first class and standing first in order of merit. This won for him the Frank Smart Prize and Fellowship for research. He worked on respiration of Cherry laurel leaves under the guidance of Professor F. F. Blackman. After the completion of two years of fellowship, he was employed by the Government of Britain for a year to devise the best method of storing apples. The results which he published jointly with Blackman in the form of papers are now classical.

During his seven years stay at Christ College, Cambridge, Parija was the Secretary and later the President of the Indian Student's Majils and came in contact with noted figures such as Jinnah, Sarojini Naidu, Tilak and many others. Birbal Sahni, Chintaman Dwarakanath Deshmukh, Afzal Hussain, Hanumanthrai, Srinivasa Ramanujam, John Mathai and others were his contemporaries at Cambridge.

On return to Orissa in August 1921, Dr Parija joined the Ravenshaw College, Cuttack, as Professor of Botany in the Indian Education Service and lived in the West Hostel as a warden. He was an ideal teacher and came in intimate contact with students who considered him as a philosopher and a guide. He taught them more by example than by precept. His classes were always lively and his lectures immensely interesting. He unfolded to his students the mysteries of plant life which inculcated in them the spirit to learn the subject in depth. Parija also helped the needy students financially. He used to contribute Rupees two hundred per month out of his salary for this purpose.

Research

It was due to Parija that the Ravenshaw College became a centre of higher learning and research in India. Many brilliant students like the late Professor S. M. Sircar, Professor T. C. N. Singh, Professor P. Misra, Professor B. Samantrai, Professor B. N. Sahu and many others were initiated into research by him.

The work carried out by him falls broadly under three categories, viz. (i) fundamental and applied aspects of plant physiology, (ii) experimental plant morphology and (iii) ecological studies of plant environment.

While at Cambridge, young Parija was given the problem of studying drifts in the rate of respiration of apples maintained in cold storage at 2.5°C. The interesting fact was that in the ripening of fleshy fruits, senescence was the dominant stage of ontogeny. Side by side with investigations on respiration of apples, a good amount of research was also carried out on respiration of evergreen leaves which continue to exist in a state of maturity for long periods. Parija wanted to determine if the two organs, the evergreen leaves and the ripening fruits, so different from each other manifested the same fundamental principles of catabolism. In the first paper of a series he wrote with Professor Blackman, in 1928, it was shown that respiration of an apple in ordinary air was an integration of two independent but opposed processes which are at work during senescence. One was the starvation drift at 22°C which tended to lower respiratory activity while the other was expressed as rise of hydrolysis activity.

In the second paper, Parija (1928) presented the behaviour of individual apples alternately in air and in nitrogen. He found CO_2 production by nitrogen respiration (NR). It was concluded that the total carbon loss was three or more times greater in nitrogen than in air. The question that arose was what happened to this deficit of carbon in air. The answer was presented by Blackman (1928) in Part III of this investigation through a scheme of reactions comprising the respiration sequence of at least half-a-dozen catalysed reactions. According to this scheme, carbohydrate reserves in apples are hydrolysed to hexoses and activated to heterohexoses which are converted by glycolysis to methyl-glyoxal. The last reactions were considered to be dependent

upon the presence or absence of O_2. In nitrogen i.e., in the absence of O_2, the final products were CO_2 and alcohol in the usual ratio. On the other hand, in air and other concentrations of O_2, the final products were water and CO_2. Thus, no carbon derivatives accumulated in the tissues finally during the OR-stage. So the logical conclusion was that in air, a part of the last stage reactants was somehow worked back into the system occasionally by O_2 and this they termed "oxidative anabolism (OA)."

On return to India in 1921 and joining as Principal, Dr Parija devoted himself to the development of Botany in the Ravenshaw College, Cuttack. It was due to his untiring efforts that this College acquired a name and became a centre of higher learning and research in Botany, particularly in Plant Physiology. He tackled both applied and fundamental problems which were considered of importance for national development. These included :

(a) *Studies on Water-Hyacinth and other Aquatic Weeds*

The spread of water-hyacinth was so alarming that expert committees were set up all over India and Burma to study the details of the life-cycle of this plant so that methods to control this obnoxious weed could be evolved. The Imperial Council of Agricultural Research granted financial assistance to Parija to study this problem in Orissa. In this scheme, studies on transpiration and absorption were conducted by the late Professor S. M. Sircar. It was found that the seeds retained their viability for seven years. The germination of water-hyacinth seeds was like that of date and Borassus. Light hastened the floating of water-hyacinth seedlings and the weed flourished in a wide range of *p*H with optimum growth at *p*H between 6 and 8. It was further shown that the plant could withstand a considerable degree of drought. Copper sulphate was found to be the most effective against not only water-hyacinth, but also against *Pistia* and *Salvinia.*

(b) *Studies on Respiration*

Parija and Saran (1934) reported that short exposures to light influenced the rate of respiration in the leaves of Aralia. Red light had no effect, while blue and violet affected respiratory rates in the same way as white light. The increase in the rate of respiration was, according to them, due to the hydrolysis of food reserves, activation of enzyme systems or change in the permeability of cells. They studied the rate of respiration of the amphibious plant *Scirpus articulatus* L. in both phases of its life cycle i.e., under water as well as in air and found that the rate of respiration of the scapes was higher in air than in water. This was ascribed to low concentration (2.3–2.6 per cent) of O_2 dissolved in water.

(c) *Studies on Transpiration and Heat Resistance*

Parija and Mallik (1936) noted that cuticle formation in *Ficus religiosa* was not induced by dryness alone but was induced when dryness was coupled with light. It was further shown that while red rays were ineffective, blue rays induced cuticle formation. In 1939, Parija and Samantarai studied the drifts of transpiration in the leaves of *Datura alba, Helianthus annus* and *Ixora undulata,* from the measurable

stage till their fall. They observed a characteristic curve of transpiration for each leaf with a rise, then a fall to a steady value and finally a decline.

Again in 1940, Parija and Malik reported that oily seeds resisted the effect of high temperatures better than the starchy ones. Amongst the oily seeds also, it was found that resistance to higher temperatures increased with increase in oil content.

(d) *Studies on Experimental Morphology*

Parija and Misra (1933) were the first to establish that the thorns on the stem of *Bridelia pubescens* Hurz were morphologically roots and were apogeotropic. Later in 1935, Parija studied peg formation in the seedlings of *Cucurbita maxima* raised from seeds germinated in different positions and under different light conditions. It was found that in seeds placed vertically with microphyle upwards, the radicle bent downwards and the pegs were formed on the concave side. On the other hand, in seeds placed vertically with their micropyle downwards, the radicle grew straight down and the pegs developed always nearest the slab. When no particular side was influenced by gravity but one side was darker, a vegetatively heliotropic peg developed on the less lighted side.

Again Parija and Malik (1936) proved experimentally that suberisation of the cell wall at the sutures of five carpels in longitudinal furrows supplemented turgescence in the cells of the fruit wall in the mechanism of bursting of balsam fruits. In 1936, Parija along with Samal studied the distribution, structure and development of glandular hairs and extra-floral nectaries in *Tecoma capensis* Lind. It was confirmed that the extra-floral nectaries originated from the glandular hairs. They suggested that the Patelliform glands probably helped in self-pollination of flowers by keeping the unwelcome ants fully fed with honey secreted by these glands and thereby prevented them from visiting other flowers, which would have brought about cross-pollination.

P. Misra in 1963 studied the occurrence of medullary cork in *Ipomoea crassicaulis*. The physiological and anatomical adaptations of this plant to varied ecological habitats were fully worked out.

In 1967, Parija studied the growth of the ovary of *Momordica dioica* when its flowers were pollinated with the pollen of *Luffa acutangula*.

(e) *Studies on Rice*

The Government of Orissa, Department of Agriculture, sanctioned a Rice Research Scheme in April 1937 and Professor Parija was entrusted with the task of investigating physiological aspects of this plant. Later, the scheme was financed by the Imperial Council of Agricultural Research from April 1, 1942 through March 31, 1945. It was found that in the rice plant, flood resistance was induced by pre-sowing treatments of seeds (i) with low temperature (2–5°C) for 6 days (ii) by subjecting the seed to anaerobiosis (O_2 free air) for 3 days or (iii) to an aerobiosis coupled with low temperature for 3 days. The treated plants survived better than the controls when submerged under water and gave a higher yield. The stem anatomy of flood-resistant varieties was rather peculiar and exhibited a sclerenchymatous band of tissue around

the cortical lacunae. It was also shown that pre-sowing treatment of seeds at higher temperature of 40–42°C induced drought resistance in rice plants.

Similarly, Parija with his team of researchers evolved a pre-sowing seed treatment with 1.7 per cent common salt solution for saline resistance and found that saline-resistant varieties had highly suberised exodermis in their roots. They also evolved various seed-treatments such as smoking, drying, dehusking and soaking with the juice of germinated grains to break dormancy in winter types for growing them as Dalua.

(f) *Studies on Algae*

During the course of investigation on the life histories of weeds of Chilka lake in connection with malaria which prevailed around that area, Parija and Parija (1946) studied the algal succession on a little rocky island named Charaiguha in the lake and found that diatoms extended through all the zones and appeared twice annually, while *Polysiphonia* appeared in January and continued till May and required moderate salinity. *Ceramium* was found growing there from February to April under high salinity conditions. *Cratolouphia* did not grow at the water edge but occupied the lowermost zone to avoid damage by the waves, and required high salinity for profuse growth. Diatoms and red algae grew in deeper waters and consequently under conditions of feeble light. Amongst the green algae that inhabited the lake, *Chactomorpha, Enteromorpha* and *Cladophora* were noteworthy. Parija and Parija also investigated the utilization of aquatic flora of the Chilka lake as raw material for manufacturing *agar-agar*.

In 1969, Parija, Patnaik and Rao in a research scheme on mass culture of algae financed by the Indian Council of Agricultural Research made as survey of the blue-green algae in the soils of Cuttack and found that *Phormidium, Microcystis, Cylindrospermum, Anabaena, Aphenotneca, Oscillatoria, Rivularia* and *Nostoc* were the predominant genera in those soils.

It was Professor Parija who initiated many of the present day botanists into research. Several of his students attained great academic distinctions and later became well known in their research careers. The importance that plant physiology gained as a field of botanical study in this country was mainly due to Professor Parija who thus became a legendary figure. He rightly came to be considered as the grand-old man of Indian Botany.

Educational Administration

Professor Parija was the Principal of Ravenshaw College, Cuttack from 1935 to 1945. He revamped the College administration with several of his new original ideas. Thus, a tutorial system in the College was started to advise and guide students by personal contact. He also introduced the system of having a student as the President of the College Union, encouraging thereby the student community to take up positions of responsibility. The success of these ideas is apparent from the fact that many student leaders became State leaders in various fields. Professor Parija was no doubt a strict disciplinarian but his decisions always had an element of

humaneness. Under his stewardship, an annual extramural lectureship was instituted in the college, which was well received by the entire educated masses of Cuttack. Magnanimous and ever ready to help needy students, Professor Parija was averse to making them dependent on charity. A student's Labour Bureau was thus started where students could work part-time and earn to sustain themselves. It inculcated in them the spirit of self-reliance and dignity of labour.

Professor Parija was the first Vice-Chancellor of Utkal University. Able leadership is crucial for the proper growth of any organisation, and more so, for an educational institution. Utkal University was fortunate in that it was able to obtain the services of an experienced and dynamic leader in Parija in the early stages of its growth. Parija had, of course, a challenging and difficult task, but he brought to bear upon it his vast and rich experience. His scientific and modern outlook, deep scholarship and unbounded humanism went a long way in moulding the Utkal University and even today it bears the stamp of his personality.

Professor Parija left the University to render service, first to the State Government and later to the Banaras Hindu University as its Pro-Vice-Chancellor from 1948 to 1951. However, he continued to be the Pro-Chancellor of Utkal University from 1951 to 1955. Again from 1955 to 1966, he provided leadership to Utkal University for two terms as its Vice-Chancellor. The University Departments of Philosophy and Sanskrit were started in 1957 and of Psychology, Statistics, Political Science and Anthropology in 1958. Professor Parija was alive to the needs of education in commerce in the State. M.Com. classes in the campus were started in 1962.

In 1945, the Development Department of the Orissa Government was reorganised and a new Department of Agriculture was created with Professor Parija as its first Director. The 'Grow more food' campaign became a success because of his leadership. During his Vice-Chancellorship of Utkal University, Professor Parija also acted as the Chairman of the Standing Committee on General Education. In 1962–63, he was elected as the Chairman, Standing Committee, Inter-University Board of India and Ceylon. He was also elected to represent the Board in the Council of the Association of Commonwealth Universities in 1963. Parija was also elected as the Vice President of the Tenth International Botanical Congress held in Edinburgh in August 1964. Earlier, as a Pro-Vice-Chancellor of the Banaras Hindu University he also became the Honorary Professor of Botany during 1949–51.

Honours

Parija was associated with a large number of scientific and academic bodies in the country and abroad. He was the President of the Botany Section of the Indian Science Congress in 1930. The Indian Botanical Society grew up under his guidance. He was member of the Patna University Senate and Syndicate for several years and rendered valuable service, in recognition of which the Patna University conferred upon him the Degree of Doctor of Science (*honoris causa*) in the year 1944. It was in 1935, that he was elected as Foundation Fellow of the National Institute of Sciences of India (now the Indian National Science Academy). In 1949, he was appointed Member of the Central Advisory Board on Forest Utilization. During

1953–54, he served as Chairman of the Expert Committee of the Government of India, Ministry of Food and Agriculture, to report on the reorganisation of the central agricultural research institutes. Again in 1955, he was appointed Chairman of the Language Commission of India. In the same year, he was awarded the *Padma Bhushan* by the President of India.

The highest award for a devoted scientific career came to Parija when he was elected General President of the Indian Science Congress Association to preside over the Bombay session held in January, 1960. Earlier he had been the General Secretary of the Indian Science Congress Association for five years. Parija was also active from 1966 to 1970 as a member of the Board of Management of Orissa University of Agriculture and Technology, Bhubaneshwar, He rendered valuable service to the University which in recognition thereof conferred on him the Degree of D.Sc. (*honoris causa*) in 1976.

Legislative Debut

Parija was not only known in scientific and academic fields but was also popular with the people of Orissa. He was elected to the Orissa Legislative Assembly from his home constituency of Balikuda as an independent candidate in 1952. He proved himself an able administrator and piloted the Cuttack Improvement Trust Scheme which became a reality two decades later. However, Parija could not fit into politics since he was not an opportunist, and hence could not retain his seat in the next general election. In Orissa, Parija had become a living legend; not only was he regarded as a great scientist but also a man of great achievements in cultural and political fields. He was, for several years, President of the Utkal Sahitya Samaj, the foremost literary organisation and of the Utkal Sammilani, the prestigeous political organisation of the Oriya speaking people.

Marriage

Parija was married, in 1922, to Shrimati Sundramani, daughter of Shri Gourang Charan Kanungo of Balinadia on the north of the river Birupa. They remained married for 56 years and by a strange coincidence Parija died only two weeks after the death of his wife in 1978. Colleagues of Parija will fondly remember Mrs Parija's kind hospitability and generous nature. She was responsible for the great achievements of Parija to a great extent. For the young students who lived in the College compound when Parija was the Principal, Mrs Parija was almost like a mother.

Parijas were survived by two sons and one daughter. One of the sons, Shri L. I. Parija, I.A.S., is Commissioner in Orissa Government and the other, Shri P. R. Parija, is a trained geologist engaged in personal business at Cuttack. Their daughter, Dr Saudamini, is Reader in Health Education in the Department of Physical Education in Panjab University, Chandigarh and is the wife of Dr R. P. Bambah, Professor of Mathematics in the same university.

Personal Attributes

Professor Pranakushna Parija was a scientist of world renown. A great scholar, a revered teacher and an eminent educationist, he was also a household

figure in Orissa because of his distinctive achievements in cultural, social and political fields as well. He was a source of inspiration and encouragement to young intellectuals and scientists, particularly to the present generation of Indian botanists. Even a brief contact with Parija evoked admiration for his simple and noble yet very rich mind, a literal Midas's touch of his luminous erudition. During his 87 years, he left an indelible impression on scientists and other public figurers of his time. Although a perfect human being is an Utopian far cry, Parija reached very near to being one. His versatility and excellence in many fields bear testimony to his capabilities.

Parija is known for his simplicity and straightforwardness. His kindness and courtesy endeared him to one and all. His concern for punctuality and demeanour was infectious. The value of time and its proper utilisation were the envious legacies left behind by Parija.

Parija had a knack of conducting meetings pleasantly and purposefully. There was no room for ambiguity or acrimony. Issues were clinched and decisions recorded in the most systematic manner. He was a well-read man and had memorised many sanskrit slokas and Oriya folk-songs, and these often served him well in easing tense moments at meetings whenever tempers flew high.

From humble beginning he rose to international heights in the realm of science and also became an erudite scholar and able administrator. He died on June 2, 1978 in Cuttack. The fragrance still lingers even though the rose has withered, leaving behind a legacy of richness and wholesomeness of a great man.

K. K. NANDA

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KAFIL AHMAD CHOWDHURY

(1902–1978)

Elected F.N.I. 1940

Birth and Early Education

Born on February 1, 1902, in a conservative zamindar family in Raipura village of Naokhali district, East Bengal, (Now Bangladesh), Kafil grew up under the care of his mother, Mrs. Hayatunnisa and elder brothers, since he lost his father, Sri Ayub Ali when he was only four. Young Kafil received his primary and secondary education at Raipura and Lakhimpur, and was later sent to Calcutta to study humanities, subjects that least interested him. A keen observer of nature from his early childhood, he was fascinated by the plant and animal life around him. As he grew up, the desire to understand and explore natural phenomena became so great that he wanted to change over to biological sciences, but it was disapproved by his family. Eventually, however, his mother permitted him on condition that he would take his first degree in the Arts.

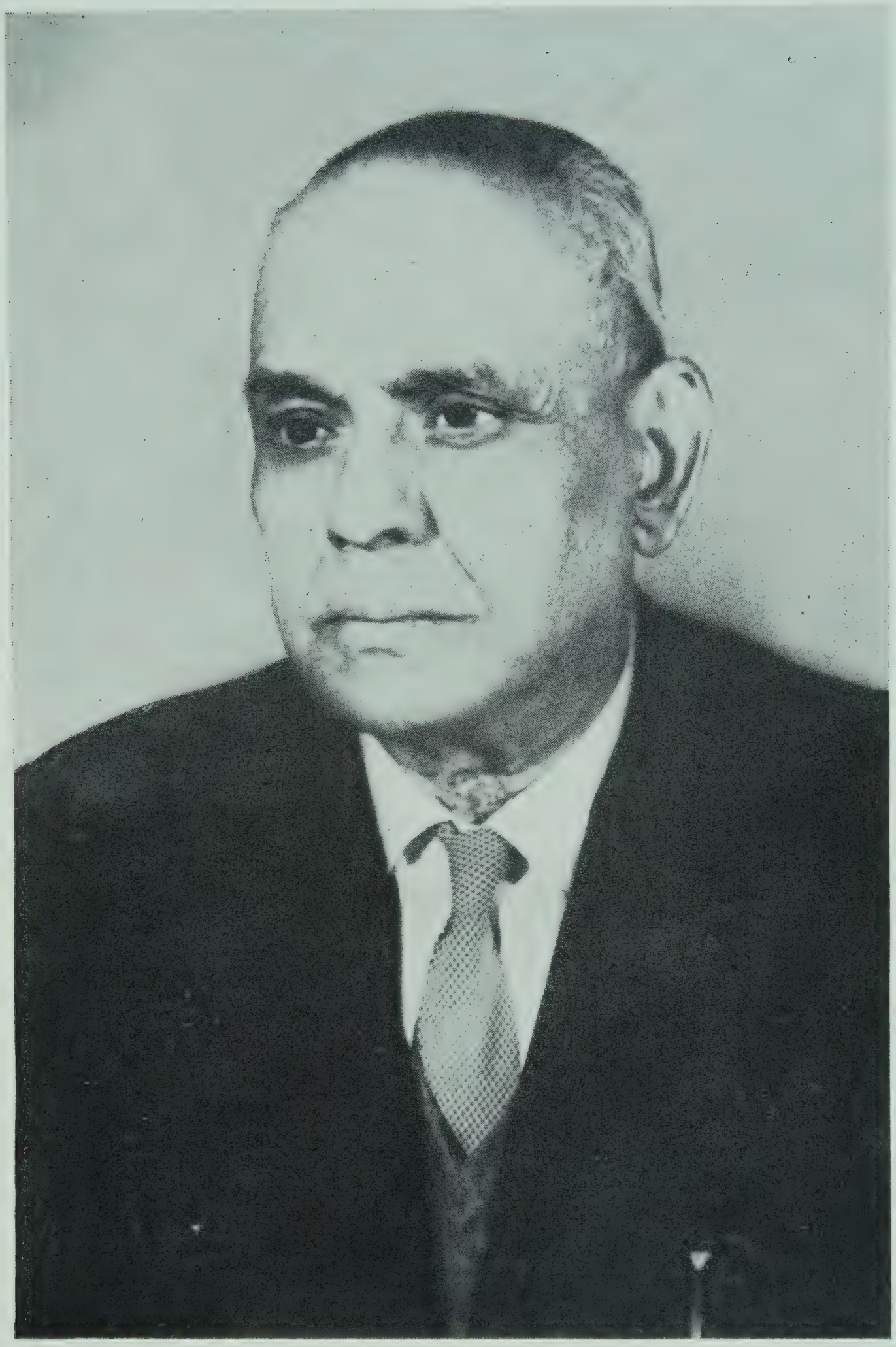
Higher Education and Professional Career

Kafil Chowdhury obtained his B.A. degree from the Calcutta University in 1922, and then left for Edinburgh to join a course in Forestry. He received his first degree in Science from the Edinburgh University in 1925, and also gained a few years research experience under the guidance of Sir William Wright Smith. During his stay in British, he developed personal contacts with some outstanding scientists like Professors Cassar Ewar, Ashworth, and Sir James Walker. They exercised a great influence and helped shape him as a scholar and scientist.

Wood anatomy had never received importance till late in the nineteenth century and the first notable attempt to describe the important timbers of India was made by J. S. Gamble (1847–1925), who published his *Manual of Indian Timbers* in 1881.

During the First World War, the fighting forces were required to be supplied with more than 600 wooden articles for their needs, and the importance of a knowledge of wood anatomy was realized. A number of wood anatomy laboratories sprang up in different parts of the world after the hostilities ended. With a view to establish a similar laboratory in India, the Government requisitioned in 1923 the services of Professor H. P. Brown (1887–1951) of Syracuse University.

The laboratories at Forest Research Institute, Dehra Dun were expanded in 1927, and Kafil Chowdhury joined as Wood Technologist on June 1, 1927. During his



K. H. Chowdhury

short stay in India, Professor Brown planned, with the help of R. S. Pearson, the then forest Economist at the Forest Research Institute, to write a book on *Commercial Timbers of India.* Kafil Chowdhury was asked to collaborate. The Government deputed him to go to Syracuse University to assist Professor Brown. The task of collecting anatomical data for the book fell upon him which he carried out for a couple of years. The book came out in 1932. It included all the information available at that time on wood anatomy, timber mechanics, wood preservation, wood seasoning and working qualities of 320 species. The work ran into 2 volumes, covering 1150 pages, and stands as a good reference text even today.

Besides collaborating with Professor Brown, Kafil Chowdhury also completed the M. S. course during his stay at Syracuse. Back home again in 1929, he continued to work with his usual ardour and enthusiasm and established a Wood Anetomy Laboratory at F. R. I., Dehra Dun, which is today one of the most renowned laboratories of its kind in the East. He was now well known as a leading scientist in this field. In recognition of his work, he obtained the D.Sc. degree of the University of Edinburgh in 1939.

Contributions to New Knowledge

At Dehra Dun, Dr Chowdhury extended his research with two main objectives : (*i*) a general survey of anatomical structure of the species already in use so as to correlate the structure with the working qualities for which they were known; and (*ii*) screening of the anatomy of all jungle woods. The intent was to identify species, with good working qualities associated with particular anatomical features, in order to exploit them for utilization. Results of these studies have proved to be of immense advantage in recognition and proper utilization of woods in India.

In the early thirties, when Indian Railways were engaged in preparing a guide book for identification of timbers used as sleepers, Chowdhury's knowledge was invaluable. He collected information on 60 relevant species; some of them were well known for their durability, while the others had to be treated chemically for protection from fungi and insects. His book entitled *The Identification of Important Indian Sleeper Timbers* appeared in 1932. It included a key for timber identification and a map indicating the areas where the species were found. A request for a similar booklet, on the identification of timbers of strategic value, came from the Defence Services. Dr Chowdhury took up the responsibility and published *"Regional Keys for the Identification of Important Timbers Used in Military Areas of Inspection, I, II, III"* in 1945. The work included a number of keys, a map and a set of photomicrographs of woods in cross-section.

During the Second World War, he published a series of booklets under the heading *How to Identify Timbers.* The series comprising 6 parts, appeared in 1942–43. The first part embodied hints on how to make a proper identification, while the others dealt with timbers for helves and tool handles (Part II), for motor lorry bodies (Part III), for boxes and packing cases (Part IV), for gun and rifle parts (Part V) and for camp furniture (Part VI).

In the early thirties, a long-term project was started at Dehra Dun to produce a book on the important commercial timbers of evey State In India. Under this

programme Chowdhury published two books, one for the Punjab and the other for West Bengal, in 1934 and 1951 respectively. The anatomical description and summaries of special properties of the woods were presented along with a hand-lens features key and photomicrographs for the identification of relevant timbers. A book on Burma timbers was published by him in 1945, when the Defence Forces felt the need for such a guide book.

After the War, timber sources and timber-based industries were brought to the fore. Consequently, there was an increasing demand for information on all available timbers of the country. It was then decided to prepare a comprehensive book on *Indian Woods* in six volumes, each dealing with 250–300 species. Chowdhury came forward and published the first volume in 1958, sharing the authorship with his colleague, Mr S. S. Ghosh. Besides providing useful general information on Indian trees and woods, the volume gives an account of their distribution and habitat. It contains information on colour, hardness, weight, grain, texture and natural durability of the woods. Anatomical structure, as seen mainly in transections with the unaided eye or with the help of a hand lens ($\times$ 10), has been duly emphasised. Other related aspects such as seasoning, insect attack, preservative treatment, working qualities, supply and uses are also dealt with. Two more volumes of this work, *Indian Woods,* have since appeared.

Professor Chowdhury undertook several short term investigations of economic importance. To mention a few, an investigation was carried out on adulteration in Sandal wood (*Santalum album*) an expensive wood usually sold by weight. It was possible to identify all the adulterants, generally cheaper woods with a similar scent, from true sandal wood, by their anatomy which can be examined with a hand lens.

Some woods are attacked and damaged by *Lyctus* insect in storage, while others are not. This problem was investigated in 1933 with a view to finding out a remedy. Professor Chowdhury showed that a correlation existed between size of the vessels and frequency of the attacks. Timbers with large vessels provide space for the insects to lay their eggs, while those with small vessels are unsuitable for this purpose. The latter needed no protective measures.

The heartwood of sal (*Shorea robusta*) is known for its durability but the sapwood is not strong. The two are distinguishable by their colours. Occasionally, one comes across logs which have the colour of heartwood but which lack in durability. Professor Chowdhury showed that the absence or presence of tyloses was a more reliable criterion of distinction. The heartwood always possesses tyloses while the sapwood lacks them even when its colour resembles that of the heartwood. Also, certain woods exhibit fluorescence under ultraviolet light. Professor Chowdhury tried to exploit this feature in distinguishing timbers which apparently look alike.

Lignum-vitae (*Guaiacum officinale*), a timber from South and Central America, is used exclusively in the ship-building industry for propeller tail-shafts because of the characteristic property of lubricating itself under water. It is, therefore, preferable to metal bearings. During the Second World War, when India was cut off from the outside world and stocks of lignum-vitae in the country got exhausted, Indian substitutes for this imported wood were sought. After extensive examination, Professor Chowdhury recommended in 1944 the red cutch (*Acacia chundra*), an

almost unknown timber, for the purpose. Though different in their anatomy, the two species have their wood cells filled with a thick gummy substance which is insoluble in water and which serves as a lubricant.

During sinking piers for the construction of a bridge over the Ganges at Mokameh in Bihar, the Chief Engineer felt some doubt about the suitability of the material supplied. Professor Chowdhury was consulted for his expert opinion about a log. He examined a piece of wood from the log and noticed a stage of deterioration in the cell wall which occurs after a wood has been left underground for more than 2000 years. This information (1957) necessitated a thorough checking of the project and averted a loss of lakhs of rupees.

Forests are managed on a commercial basis, hence, it is necessary to ensure that trees put on adequate volume of wood per year so as to give a profitable return to the capital expenditure incurred in growing a forest. This is easy to determine in temperate species where annual growth rings are often prominent. In the tropics, the outward appearance of the trees gives an impression of a continual growth all the year round that may avoid the formation of growth rings. In order to determine the actual condition of radial growth in tropical trees, Professor Chowdhury undertook a long term research programme and worked out (1939, 1940) the cambial activity of a number of forest trees in North India. The species studied include cutch (*Acacia catechu*), siris (*Albizzia lebeck*), semul (*Bombax malabaricum*), toon (*Cedrela toona*), sissoo (*Dalbergia sissoo*), champ (*Michelia champaca*), chir (*Pinus roxburghii*), sal (*Shorea robusta*), jaman (*Syzygium cumini*), teak (*Tectona grandis*), and laurel (*Terminalia tomentosa*). Of these, sal and jaman did not show growth rings; chir, teak and toon exhibited clear growth rings; laurel and champ showed demarcation of rings by concentric bands of parenchyma occurring at more or less regular intervals. In the remaining species, growth rings could bet raced only after a careful microscopic examination of the shape and size of the various cells produced in different seasons in a year.

In all the species, however, radial growth was periodic rather than continuous. The cambium remained active for about 5–9 months, winter usually being the period of rest. According to Professor Chowdhury, "there are indications that the local temperature plays an important role in the renewal of cambial activity. The diameter growth usually starts when temperature is maximum in the year or near about it. Growth once started continues even when the temperature usually decreases. Local temperature does not show any relation with the cessation of growth." On the basis of his investigation on mahogany (*Swietenia macrophylla*) and teak (*Tectona grandis*) from several agro-climatic regions, he inferred (1940) that prolonged cambial activity did not necessarily result in a large amount of wood. Teak trees in Nilambur (West Coast) and Kaptai (East Coast) had the cambium active for about six months in the year and those at Dehra Dun (North India) for about four months. However, there was only a little difference in the volume of wood produced at the three localities. He further pointed out (1954) that the size and structure of protoxylem and metaxylem were influenced by the rate of extension growth of the shoot. He emphasised the difference between temperate and tropical trees with regard to foliar development and cambial activity, phases of extension and radial growths.

In 1934, Professor Chowdhury made valuable suggestions for the control of various defects of papita wood (*Pterocymbium tinctorium* = *Stercula companulata*) which was extensively used for the manufacture of matches.

Based on growth rate and timber quality, Professor Chowdhury solved a ticklish problem during the last world war by suggesting Indian Spruce (*Picea smithiana*) as a substitute for sitka Spruce (*Picea sitchensis*) of North America which was then used for the bombers of the Air Force.

Professor Chowdhury recognized three categories of diffuse-porous dicotyledonous woods; (*i*) permanently diffuse-porous, unaffected by environment, e.g., *Acer, Cornus,* and *Michelia*; (*ii*) usually diffuse-porous, but occasionally semi diffuse-porous or semi ring-porous, the variation not being influenced by environmental changes, *Diospyros, Juglans, Swietenia, Terminalia*; and (*iii*) diffuse-porous under favourable environments but becoming semiring-porous to ring-porous under extremely unfavourable ones e.g., *Butea, Grewia, Salix* etc. In 1953, he noticed a peculiar variation in gross structure of a single species, *Gmelina arborea* (Verbenaceae). The wood showed not only diffuse-porous and ring-porous characteristics but also all the intermediate types between these two extremes within a single tree. No other species has so far been reported showing this peculiarity. Professor Chowdhury asserted that contrary to the general belief, tropical species like *Lagerstroemia speciosa, Tectona grandis* exhibited true ring porous structure. He noted (1963) that even some evergreens e.g., *Colubrina* spp., *Peronema* spp. *Pterocarpus dalbergioides* etc. produced ring-porous woods under tropical climates.

He enunclated on the basis of his observations that in some species, the nature and extent of various wood elements underwent changes in relation to the environment but remained unaffected in others. In case of *Portium serratum* (Burseraceae), for example, the high percentage of septate fibres remains constant with changing environment, while in *Lagerstroemia speciosa* (Lythraceae), it varies from locality to locality (1956). Similar results were obtained for apotracheal parenchyma (1954).

The discovery of "initial parenchyma" is associated with the name of Professor Chowdhury. It was noticed in species like *Dalbergia sissoo* (Leguminosae), *Entandrophragma macrophyllum* (Meliaceae), *Salix malsudana* (Salicaceae), *Swietenia macrophylla* (Meliaceae) and *Terminalia tomentosa* (Combretaceae), where a thin concentric band of parenchyma was produced as the first tissue of the season's growth. This was the first report in diffuse-porous species. Keeping in view their position in a growth ring, the cells were termed "initial parenchyma." Some criteria for distinguishing the "initial parenchyma" from "terminal parenchyma" were also developed (1934, 1936). Recognition of these parenchyma cells helped in tracing the conversion of diffuse-porous to ring-porous structure. In *Gmelina* (1953), it was described to occur in three steps (*i*) appearance of "initial parenchyma" in diffuse-porous wood; (*ii*) appearance of some vessels in the vicinity of these cells; and (*iii*) embedding of some large vessels of early wood in the "initial parenchyma" and reduction in the tangential diameter of late vessels.

Speculating upon some evolutionary trends in the secondary xylem of flowering plants, Professor Chowdhury said (1953) in a symposium :

(a) *The diffuse-porous structure is the oldest among the dicotyledons, the semi-ring-porous and true ring-porous evolved later on.* (b) *In the survival and evolution*

of these plants, the genetic mechanism appears to have played the greatest part. The plasticity of the genetic components has been responsible for evolution in different directions. The non-plastic and weak have been eliminated, as they could not face the environmental changes brought about during the geological ages. The non-plastic but strong have survived and are still in existence as in the past. The plastics have forked out in two directions—the semiring-porous and true ring-porous, depending on the freedom inherent in the plasticity of their genetical make-up.

He also pointed out (1966) that the seedlings of perennials usually had irregular growth activities both externally and internally. After expiry of the juvenile stage, a rhythmic growth sets in which lasts for the rest of the plant life.

It is usual to classify plants initially on the basis of their external morphology and then their internal structure. It often happens that anatomical studies reveal facts in apparent conflict with those of external examination. This happened in *Mansonia dipikae* (Sterculiaceae). A log of wood was sent from Assam to the Foerest Research Institute, Dehra Dun, under the name *Pterygota alata*. The anatomical features, however, indicated (1956) that it was a new genus. A thorough and extensive investigation including examination of wood samples finally led to the discovery of *Mansonia dipikae*—a first record of the genus in India.

Apart from his contributions to wood anatomy, Professor Chowdhury also devised new techniques for anatomical studies. Most tropical woods are hard to very hard and have to be treated with hydrofluoric acid for 6–8 weeks to soften them for sectioning. Professor Chowdhury introduced (1934) an improved method for softening the hard woody tissues in HF under pressure. Usually, 80 lb per inch pressure gave satisfactory results and even very hard Indian timbers take only 7–10 days to soften. Besides, for the identification and classification of woods, anatomists have been using dichotomous keys similar to those used by systematists. These are often confusing to workers especially when a large number of species are involved. Professor Chowdhury devised perforated card keys (1942) to ease the situation. The method was improved considerably by his colleagues and pupils later on. Furthermore, he also formulated criteria for a proper distinction of true growth rings from the false ones.

Wood anatomy Laboratories were established in India after the First World War, but fossil woods received attention only in the mid-thirties. The first fossil wood from the Miocene bed of Assam was studied by Professor Chowdhury (1934, 1936) and identified as *Glutoxylon*. It resembled Holden's *Dipterocarpoxylon* from Burma and Colani's *Dipterocarpoxylon* from Indo-China. After a critical examination of all the available material, he suggested (1952) that Holden's and Colani's specimens together with the one from Assam be placed under a new species, *Glutoxylon burmense*.

In a joint session of Palaeobotany and Wood Anatomy sections of the 8th International Botanical Congress held at Paris in 1954, Profesor Chowdhury delivered his Presidential address "Dicotyledonous fossil woods : convergent wood structure" and outlined the advances wood anatomists had made in systematic identification and classification of extent as well as extinct species. At the next International Congress held at Montreal in 1959, he discussed the significance of the evolution of "initial parenchyma" based on the actual findings in a Miocene fossil wood from

Burma. In 1960, he discovered a new wood, *Pahudioxylon indicum* from Bankura, West Bengal.

It has long been noticed by students of fossil dicotyledonous woods of India that Miocene woods often match with living ones; woods from earlier formation, especially from the upper Cretaceous to Eocene, were different. This apparent difference between the vegetations of Miocene and Eocene had no explanation. However, students of rock magnetism have shown that 70 million years ago, the Deccan trap from which the Eocene woods of India come, was situated 30° latitude south of Equator. Peninsular India has slowly drifted north and is now situated about 20° north of Equator. Based on this, Professor Chowdhury suggested (1966) that during the northward movement of the land mass, volcanic eruptions wiped out much of Eocene vegetation. Miocene flora got established later. The new flora moved further north and now includes many genera of the Malayan region. Some of these Malayan genera have vanished in the North due to unfavourable climatic conditions. Some have however, found shelter in South and East India where the climate is somewhat similar to that of Malaya. Thus, botanical evidence from peninsular India, like that from East Africa and Malaya, strongly supports the theory of continental drift.

Chowdhury found that some of the fossil wood specimens could be traced upto their families only, others upto the genera and only a few upto the species. Apart from Indian materials, he also described (1959) a Tertiary lignite collected during an extension of the 8th International Botanical Congress to Rochessauve (Massaf Central Francis) and named it *Pinuxylon grangeonii*.

In 1950, while studying the minute anatomy of fossi and buried woods, Professor Chowdhury noticed that the axial parenchyma and ray cells retained their original wall structure much longer than the fibres. The reason was not known. Later, he discovered, on the basis of his observations on bamboos (*Dendroclamus strictus*), that the two tissues differed in their reaction to delignification (1957). To start with, the lignin content of fresh fibres and parenchyma cells is about 28.8 per cent and 27.4 per cent respectively. Delignification for one hour brings down the content to 8.3 per cent and 11.6 per cent. Continued delignification for over 5 hours results in the fibres showing 2.8 per cent and the parenchyma 5.5 per cent of lignin. At this stage the parenchyma remains intact while the fibre walls are disorganised and the elements are set free. Thus, the slower rate of delignification of parenchyma explains, at least partly, why the fibres disintegrate more quickly than the parenchyma in the fossil and ancient woods (1957).

Durability is an important factor in evaluation of timbers. Degradation of wood is often due to fungi, bacteria or insects. Even so, timber does disintegrate in about 2000 years even in the apparent absence of attacking organisms. In a study of four ancient Indian woods, viz., *Lagerstroemia speciosa* (7500 yr), *Mesua ferrea* (4700 yr), *Shorea robusta* (2000yr) and *Tectona grandis* (2200yr), Professor Chowdhury demonstrated (1967) that underground burial of wood for prolonged periods led to a gradual reduction in cellulose, both amorphous and crystalline. He further speculated that degeneration of cellulose in the apparent absence of micro-organisms appears to proceed by a relatively rapid removal of amorphous or

paracrystalline cellulose accompanied by a slower conversion of crystalline to non-crystalline cellulose.

Having contributed a great deal to the understanding of fresh as well as fossil woods, Professor Chowdhury switched over to the study of archaeobotanical material and his work on *Ancient Agriculture and Forestry in North India* bears real testimony to his deep involvement in the subject. It deals with the state of agriculture and forestry in the Upper GangaValley during B.C. 2000 to 50 B.C. and elucidates how the inhabitants of the valley turned from food gatherers to food producers. With 3 maps, 12 tables and 16 plates, the volume presents botanical evidence on some topical questions relating to the Aryans, their religion, the frequency of their arrival in the Ganga Valley, the route they followed and the treatment they received from the indigenous populations. Evolutionary trends in some cultivated plants are also discussed; the main object, however, is an investigation of the significance of plant remains in relation to the development of ceramic culture and progressive improvement in the use of metal.

In 1950, Professor Chowdhury had the opportunity of examining the oldest archaeological wood remains recovered from Harappa. The timbers which had been used for a coffin were identified as deodar (*Cedrus deodara*) and rosewood (*Dalbergia latifolia*). Discovery of these woods from Harappa, where they do not now grow, was interesting. Another important timber excavated there was ber (*Zizyphus* sp), which was used as a mortar for pounding grains, a purpose for which it is eminently suitable due to its good seasoning and shock absorbing capacities.

Completely charred materials recovered from Hastinapura excavation were identified by Professor Chowdhury (1955) as wood remains of sissoo (*Dalbergia sissoo*) and Kurchi (*Holarrhena antidysentrica*). He also studied (1946, 1950) the archaeolological timbers excavated from Arekamedu near Pondicherry (*Diospyros, Heritiera* and *Mimusops*), from Sisupalgarh, Bhubaneswar (*Acacia* sp. *Boswellia serrata, Casearia* sp., *Holarrhena antidysentrica* and *Soymida febrifuga*), and from gem pits of Sabargamuva province of Sri Lanka (*Lagerstroemia speciosa* and *Mesua* sp.). The botanical and archaeological significance of these findings was also discussed in some detail (1955, 1965).

In 1955, he found in the mud walls from the ancient houses of Hastinapura charred material, resembling a ball of coal-tar, which on examination turned out to be a lump of burnt paddy. Occurrence of large cells arranged in parallel longitudinal rows and tangentially stretched cells of perticarp along wit h a chess-board pattern of the entire outer surface led to the identification of *Oryza* sp. In his own words, "*The interesting point was that the paddy from Hastinapura was the first direct evidence of use of rice by ancient men in India and outside. That was about 300 years ago. Use of rice husk as a binding material for mud wall at Hastinapura indicated knowledge of rice by ancient men much earlier than the age of Hastinapura would show. Such a deep knowledge in the by-produt of rice would only be possible when rice had been in use for some hundreds of years.*" This was later confirmed (1961) by S. S. Ghosh, who reported rice among the plant remains from Lathol, Gujarat—a contemporary of the Harappan civilization. This takes back the use of rice in north India to about 4000 years. The mud wall recovered from Hastinapura showed grass-like leaves

and stems arranged both horizontally and vertically. The idea was perhaps to strengthen the wall, which was again reinforced with plaster of mud mixed with rice husk. These stems and leaves were identified as *Saccharum sponteneum,* the wild sugarcane. This method of building houses is still in practice in many rural parts of India (1968).

Dr L. Durpee of the American Museum of Natural History collected a mud brick from an altar-shrine complex at Deh Morasi Ghundai, about 25km southwest of Kandahar (Afghanistan). It was sent to Professor Chowdhury who identified the grains, stem and leaves of grasses embedded in the brick. One of the grasses was of *Hordeum* sp., most closely resembling *Hordeum vulgare* variety *afghana,* and the other *Aegilops tauschii* = *Aegilops squarrosa.* The latter is now a fodder grass in many parts of the world, but its presence at Deh Morasi was believed to have some significance because, according to some plant breeders, it is an ancestor of wheat.

It is thus established that Indian Plant Anatomy in general and Wood Anatomy in particular owe a great deal to Professor Chowdhury. He was the first Indian scientist to make notable contributions.

Dr Chowdhury became Chief Research Officer in May 1947 and later held the post of P. A. to the President, Forest Research Institute & Colleges from March 1954 till his retirement in December 1956.

Honours

Professor Chowdhury earned the recognition of various scientific bodies in India and abroad. In 1940, he was elected Fellow of the Indian National Science Academy, and in 1945, was conferred upon the title of MBE for his wartime services. A member of the International Association of Wood Anatomists, Professor Chowdhury presided over the Botany Section of the Indian Science Congress held at Patna in 1948. He was President of the Indian Botanical Society in 1954. He was India's delegate to the 7th and 8th International Botanical Congresses held at Stockholm and Paris in 1950 and 1954 respectively. At the latter session, he presided over two symposia, on Anatomy and Palaeobotany. He was also invited to attend the 9th, 10th and 11th International Botanical Congresses held at Montreal, Edinburgh and Seattle respectively. He was Honorary Vice-President of the 10th Congress at Edinburgh in 1964. He also presided over a section of the Pacific Science Congress held at Honolulu in 1961. He was Vice-President of the UNESCO Conference on *Contribution of People of Central Asia in the Development of Sciences* held at Islamabad in 1970.

For his meritorious services as a scientist in the field of Wood Anatomy, for over 25 years, Dr Chowdhury was awarded a "Jubilee Medal," in 1956 on the occasion of the Golden Jubilee Celebrations of the Forest Research Institute, Dehra Dun.

In 1956, Professor Chowdhury was offered the Chair of Botany at the Aligarh Muslim University by the late Dr Zakir Husain, the then Vice-Chancellor of the University. It was during his tenure that the Department took its present shape and a large Botanic Garden-cum-Research Station came into existence. He taught Plant Anatomy and Economic Botany both at the undergraduate and post-graduate levels. He also guided research on Plant Anatomy, Tropical Tree Growth and Archaeo-

botany, and several of his students earned their Ph. D degrees. He also served as the Dean, Faculty of Science. Under a joint programme of the Indian Botanical Society and the UNESCO Science Cooperation Office for South Asia, he compiled the research work on Wood Anatomy carried out in India, Burma and Sri Lanka. It was published by the Aligarh Muslim University Press in 1968. Concomitantly, he edited a book on "*Recent Advances in the Anatomy of Tropical Seed Plants*," which came out in 1969. Further, he was commissioned by the Council of Scientific and Industrial Research, New Delhi, to write a monograph on *Abies* and *Picea*. The monograph appeared in 1974.

A man of deep knowledge, Professor Chowdhury always kept abreast of the progress in several areas in Botany. As Visiting Professor, he worked in a number of leading laboratories and delivered lectures in the Universities of Cornell, Hamburg, Leeds, Munich, Syracuse and Yale. He was an active member of a number of learned societies and organisations in India and elsewhere.

On his retirement from the University service in 1968, Professor Chowdhury continued his research work on the plant remains from ancient archaeological sites in order to trace the origin and history of cultivated plants. Active in Botany until his death, he published his last book "*Ancient Agriculture and Forestry in North India*" in 1977. A good deal of his work on plant remains from Atranji Khera and Lal Qila (U.P.) and from Tepe Yahya (South Iran) etc. still remains unpublished.

A Great Phytoanatomist

He was the author of more than a hundred publications, including eight important books. His writings were precise, clear and made delightful reading. Leading phytoanatomists have paid homage to this veteran savant through their contributions to a commemoration volume released on his 70th birth anniversary. In the words of Professor C. R. Metcalfe, "*Professor Chowdhurp has been, for many years, and still is, one of India's leading torch bearers in his own special field of Plant Anatomy.*"

During the last few years of his life he suffered from stomach ulcers, which in no way deferred him from his involvement in academic life. His perseverance even under physical stress will always be an example to his colleagues and students. As a teacher, he combined sympathetic guidance with high standards, his gracious dignity winning the appreciation and devotion of his students. A valued colleague, a sincere firiend and wise counsellor, Professor Chowdhury was always helpful. Fortunate indeed are those who knew this great and gifted man.

A brilliant career ended on September 3, 1978 when Professor Kafil Ahmad Chowdhury breathed his last He is survived by his wife, two sons and a daughter. The elder of his sons, Murad Chowdhury, is an architect while the younger, Javed Chowdhury is an Officer in the Indian Administrative Service.

A. K. M. Ghouse
Muhammad Iqbal

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